Rocky Mountain Subalpine-Montane Riparian Woodland Ecological System

Ecological Integrity Assessment

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TABLE OF CONTENTS

List of Tables

A. INTRODUCTION

A.1 Classification Summary

CES306.833 Rocky Mountain Subalpine-Montane Riparian Woodland

Division 306, Woody Wetland
Spatial Scale & Pattern: Linear **Classification Confidence**: medium
Required Classifiers: Natural/Semi-natural, Vegetated (>10% vasc.), Wetland
Diagnostic Classifiers: Montane [Upper Montane], Montane [Montane], Forest and Woodland (Treed), RM Subalpine/Montane Riparian Shrubland, Riverine / Alluvial, Short (<5 yrs) Flooding Interval

HGM: Riverine

Non-Diagnostic Classifiers: Montane [Lower Montane], Drainage bottom (undifferentiated), Floodplain, Stream terrace (undifferentiated), Valley bottom, Temperate [Temperate Continental], Needle-Leaved Tree, Broad-Leaved Deciduous Tree, Circumneutral Water

Concept Summary: This system is comprised of seasonally flooded forests and woodlands found at montane to subalpine elevations of the Rocky Mountain cordillera, from southern New Mexico north into Montana, and west into the Inter-mountain region and the Colorado Plateau. This system contains the conifer and aspen woodlands that line montane streams. These are communities tolerant of periodic flooding and high water tables. Snow melt may create shallow water tables or seeps for a portion of the growing season. Stands typically occur at elevations between 1500-3300 m (4920-10,830 feet) rangewide and are confined to specific riparian environments occurring on floodplains or terraces of rivers and streams, in V-shaped, narrow valleys and canyons (where there is cold air drainage). Less frequently, occurrences are found in moderate-wide valley bottoms on large floodplains along broad, meandering rivers, and on pond or lake margins. Dominant tree species include *Abies lasiocarpa*, *Picea engelmannii*, *Pseudotsuga menziesii*, *Picea pungens*, *Populus tremuloides,* and J*uniperus scopulorum*. Other trees and shrubs that may be present include *Alnus incana*, *Abies concolor*, *Pinus contorta*, *Populus angustifolia*, and *Acer negundo*.

Ecological Divisions: 204, 304, 306
TNC Ecoregions: 11:C, 18:C, 19:C, 20:C, 21:C, 25:C, 4:P, 6:P, 68:C, 7:C, 8:C, 9:C
Subnations/Nations: AB:c, AZ:c, BC:c, CO:c, ID:c, MT:c, NM:c, NV:c, OR:c, SD:c, UT:c, WA:c, WY:c

A.2 Ecological System Description

- ### A.2.1. Environment

Climate

A continental climate dominates the Southern Rocky Mountains producing warm, dry summers and cold winters and an overall semi-arid climate. Evaporation generally exceeds precipitation, especially at lower elevations and in the intermountain basins; however, increasing precipitation and lower temperatures at higher elevations tends to reverse this trend, although aspect, topography, and intense solar radiation can moderate these effects on the evaporation/precipitation ratio (Laubhan 2004). The ratio between evaporation and precipitation has a strong influence on the hydrology of wetlands throughout the region.

Geomorphology

The Southern Rocky Mountains are composed of various igneous, metamorphic, and sedimentary rocks (Mutel and Emerick 1984; Windell et al. 1986). The mountain valleys are relatively young topographical forms created by the erosional effects of flowing water and glacier movement (Windell et al. 1986). Intermountain basins were formed from tectonic and volcanic events which occurred during mountain-forming processes (Windell et al. 1986). The valleys of these basins are now filled with deep alluvial deposits derived from erosional processes in the nearby mountain ranges (Windell et al. 1986). Glaciation has had a large influence on landforms at high elevations through large-scale erosional and depositional processes.

Hydrology

The interaction of climate and geomorphology has a strong influence on local hydrological processes in a wetland. For example, snowmelt at high elevations contributes a large proportion of water to most wetland types through its influence on groundwater and surface water dynamics (Laubhan 2004). In mountain valleys, snowmelt and geomorphology are major factors controlling the extent, depth, and duration of saturation resulting from high groundwater levels and also exert controls most aspects of the frequency, timing, duration, and depth of flooding along riparian areas (Laubhan 2004). Wetlands and riparian areas in intermountain basins are also affected by snowmelt via its association with the contributing surface water to the valley aquifers.

Flooding from the stream channel recharges many alluvial aquifers and as stream flow decreases the trend is reversed as the alluvial aquifer begins to recharge stream flow (Hubert 2004). Groundwater levels in riparian areas are dependent on the underlying bedrock, watershed topography, soil characteristics, and season (Rink and Kiladis 1986). In areas of thin soils, little surface water is retained as groundwater; however in areas of deep alluvial material, surface water collects in alluvial aquifers which support numerous wetlands and riparian areas (Rink and Kiladis 1986). The level of the water table in alluvial aquifers varies temporally and spatially depending on the distance from the stream channel, time since streamflow has increased or decreased (or flooded), geometry of the river valley, and the composition of the alluvium (Hubert 2004). The temporal and spatial variation of the level of the alluvial aquifer is an important determining factor in the distribution and types of riparian habitats present (Hubert 2004). However, alluvial aquifers are not extensive in riparian woodlands.

Surface water flow and flooding is a function of snowmelt, watershed and valley topography and area, late-summer rainfall, and the extent of upstream riparian wetlands (Rink and Kiladis 1986). For example, riparian areas which are steep are not prone to as much flooding as riparian areas in more gently sloped and broad valleys (Mitsch and Gosselink 2000). Watershed area also affects surface flow, which has subsequent effects on channel dimensions and varies according to stream discharge (which generally increases with increasing drainage basin area). Baker (1989) notes that in Western Colorado, montane and subalpine streams typically have mean discharges < 71 m^3 sec^{-1} and that historic peak discharges are less than 990 m^3 sec^{-1}, which are small for similar sized basins in other areas. Upstream wetlands and riparian areas release water throughout the growing season and are an important contribution to streamflow during later-summer and/or drought periods.

Surface water is a very important formative process in riparian areas. Flooding inundates vegetation, can physically dislodge seedlings/saplings, and alter channel morphology through erosion and deposition of sediment. Flooding in subalpine-montane streams occurs annually in May and June with the volume and duration affected by snowpack levels (Baker 1987). Occasional September flooding may occur due to intense convective thunderstorms, however these are often very localized (Baker 1987). These thunderstorms can result in sporadic and frequent small-scale flooding in small mountain streams (Hubert 2004). Interannual variation of streamflow can range from 60-150% of the mean annual flow on the west slope, whereas eastern slope streams have less variation (Baker 1987). Runoff from adjacent hillsides can also contribute to the hydrological regime of riparian shrublands by recharging local alluvial aquifers and supporting wetland vegetation that is otherwise disconnected from stream flow (Cooper 1990).

Riparian areas can generally be referred to as confined or unconfined streams. Gregory et al. (1991) have defined confined streams as those whose valley floors are less than twice the width of the active stream channel. Confined streams typically have relatively straight, single channels flowing through narrow valley floors (Gregory et al. 1991). Flooding in confined streams increases stream depth and flow velocity increases rapidly as discharge increases due to minimal lateral floodplain areas (Gregory et al. 1991). Confined streams typically have shallow soils with minimal alluvium deposition (Hubert 2004). Unconfined streams lack lateral constraint and are typically found in low-gradient, lowland areas or in glaciated valleys and intermountain basins in the mountainous regions. Meandering occurs in unconfined streams where the gradient is low (Hubert 2004). The meander process leads to the formation of a complexity of geomorphic surfaces which support a diverse array of riparian habitats such as point bars, oxbows and backchannels, natural levees, ridges and swales, and pools and riffles in the stream channel, etc. (Hubert 2004; Gregory et al. 1991). These geomorphic surfaces support many different type of vegetation communities such as early seral plant communities, emergent vegetation associated with oxbows and backwater areas, decadent stands of vegetation (Hubert 2004; Gregory et al. 1991). Due to the diversity of abiotic and biotic patches created by the meander process, perennial, low-gradient streams support the most extensive riparian habitat in the Intermountain West (Hubert 2004). Riparian woodlands are most commonly found along confined reaches and thus meandering is not common in this system.

Glaciation in the Southern Rocky Mountains has a large influence on the presence and distribution of riparian shrublands. Many high elevation river valleys (known locally as "parks") experienced glaciation during the Pleistocene and terminal moraines extend to about 2550 m in the north and 3000 m in the southern part of the region (Baker 1987, 1989; Windell et al. 1986). High elevation streams which occur in the glaciated valleys (e.g. U-shaped valleys) traverse a flat gradient and are typically dominated by riparian shrublands (e.g., Rocky Mountain Subalpine-Montane Riparian Shrubland), wet meadows (Rocky Mountain Alpine-Montane Wet Meadows), and marshes (North American Arid Freshwater Marsh) while others have a steep gradient (e.g., V-shaped valleys) and are typically dominated by the riparian woodlands (e.g., Rocky Mountain Subalpine-Montane Riparian Woodland) (Baker 1987; Windell et al. 1986). Streams below the extent of glaciation are typically steep and although those within intermountain basins often flow through broad valleys (e.g., Rocky Mountain Lower Montane Riparian Woodlands and Shrublands). Thus, geomorphology has a strong influence on the distribution of riparian vegetation (Baker 1989).

Beaver, although an important hydrogeomorphic variable in Rocky Mountain Subalpine-Montane Riparian Shrublands and Lower Montane Woodlands and Shrublands are of less significance in riparian woodlands as the steep nature of the latter sytem typically precludes beaver activity. However, beaver activity can occur, especially in those areas dominated by aspen (*Populus tremuloides*).

▪ A.2.2. Vegetation & Ecosystem

Vegetation

Vegetation within this system has a moderately dense to dense (60-100%) tree canopy dominated by needle-leaved, evergreen trees up to 30 m. in height or mixed-deciduous, broad-leaved trees up to 35 m. in height. Dominant tree species include subalpine fir (*Abies lasiocarpa*), white fir (*A. concolor*), Engelmann spruce (*Picea engelmannii*), blue spruce, Douglas fir (*Pseudotsuga menziesii*), lodgepole pine (*Pinus contorta*), aspen, narrowleaf cottonwood (*Populus angustifolia*), box elder (*Acer negundo*), and Rocky Mountain juniper (*Juniperus scopulorum*).

The overall shrub layer ranges from sparse to moderate cover (0-70%). There is a tall shrub layer ranging from sparse to moderate cover (0-70%). A short shrub layer may also be present in sparse to moderate (0-60%) amounts. Associated shrubs may include thinleaf alder, Drummond's willow, red-osier dogwood, river birch (*Betula occidentalis*), Rocky Mountain maple (*Acer glabrum*), shrubby cinquefoil (*Dasiphora floribunda*), Wood's rose (*Rosa woodsii*), narrowleaf willow (*Salix exigua*), twinberry honeysuckle (*Lonicera involucrata*), and occasionally other willows (*Salix* ssp.).

The herbaceous layer is generally sparse but may be well developed depending on shading from the shrub and tree canopy layer and may be dominated by mesophytic forbs and graminoids less than 1 m in height. The forb layer is generally sparse (10-25%) and characteristic species include Richardson's geranium (*Geranium richardsonii*), stinging nettle (*Urtica gracilis*), Fendler's cowbane (*Oxypolis fendleri*), tall fringed bluebells (*Mertensia ciliata*), common cowparsnip (*Heracleum maximum*), heartleaf bittercress (*Cardamine cordifolia*), field horsetail (*Equisetum arvense*), arrowleaf ragwort (*Senecio triangularis*), red baneberry (*Actaea rubra ssp. arguta*), Rocky Mountain hemlock parsley (*Conioselinum scopulorum*), starry false lily of the valley (*Maianthemum stellatum*), cutleaf coneflower (*Rudbeckia laciniata*), Virginia strawberry (*Fragaria virginiana*), bluntseed sweetroot (*Osmorhiza depauperata*), alpine pennycress (*Thlaspi montanum*), common yarrow (*Achillea millefolium*), largeleaf avens (*Geum macrophyllum*), and brook saxifrage (*Saxifraga odontoloma*). The graminoid layer may be sparse to dense (0-60%). Species may include bluejoint reedgrass (*Calamagrostis canadensis*), sedges (*Carex* spp.), and rushes (*Juncus* spp.).

Biogeochemistry
Bedrock geology, soil characteristics, and discharge of the contributing watershed basin determine the type and amount of nutrient flux in riparian woodland (Knud-Hansen 1986). Nutrient concentrations in high elevation streams in Colorado tend to be nutrient poor and are related to stream flow (Knud-Hansen 1986). Further downstream, bedrock geology has a large influence on nutrients in stream water. For example, thin coarse soils associated with granitic bedrock are nutrient poor and tend to be acidic, whereas soils derived from limestone or shale outcrops have more nutrients and a higher pH (Knud-Hansen 1986). Groundwater can also contribute nutrients via subsurface hillside runoff into riparian areas (Cooper 1990).

Riparian areas may serve as important biogeochemical filters of nutrients and sediment before they enter the stream from adjacent human land uses, although the limited floodplain found in riparian woodlands may limit the extent to which this occurs in this system (Peterjohn and Correll 1984, Corley et al. 1999).

Riparian woodlands are also important nutrient sources as they provide sources of particulate and dissolved carbon (e.g., detritus) to the stream which are crucial food sources for aquatic invertebrates in local environments as well as downstream areas (Gregory et al. 1991; Kattelmann and Embury 1996).

Productivity
In general, productivity in terrestrial environments tends to decline with increasing elevation and aridity (Manley and Schlesinger 2001. Because riparian areas contain perennial or intermittent water, they often have higher primary productivity than adjacent upland systems, especially in the semi-arid portions of the Southern Rocky Mountains, and thus have been suggested to be the most productive and diverse parts of the western

landscape (Gregory et al. 1991; Kattelmann and Embury 1996; Knud-Hansen 1986). In addition, species richness of montane and subalpine riparian areas in the Southern Rocky Mountains was found to be as rich or richer than riparian ecosystems in the southwest, central, and northeast portions of the United States and was found to have higher species richness than most temperate North American forests (Baker 1990). In Colorado, Baker (1990) found that species richness was highest in subalpine riparian forests (mean of 57.8 species/0.1 ha) on the West Slope while Peet (1978) found that montane riparian forests on the East Slope was highest (mean of 60.3 species/0.1 ha). Undisturbed riparian shrublands on the West Slope had an average of 47 species/0.1 ha in lower subalpine willow carrs while upper subalpine willow carrs had 52.9 species/0.1 ha (Baker 1990).

The spatial complexity of patch types in the riparian zone results in a high edge-area ratio creating many ecotones with contrasting environmental processes and habitat types (Knud-Hansen 1986; Manley and Schlesinger 2001). This spatial heterogeneity supports numerous types of plant communities which provide for abundant secondary productivity of riparian areas (i.e. abundant support of fauna taxa). Riparian vegetation also shades streamside aquatic habitat and therefore regulates stream temperatures which as large implications on habitat quality for aquatic invertebrates and fish.

Animals

The spatial complexity of riparian areas supports numerous vegetation types which in turn support a variety of aquatic and terrestrial invertebrates. These invertebrates process detritus, consume vegetation, and provide abundant food resources for other taxa such as birds, mammals, fish, amphibians, and other invertebrate species.

In the Sierra Nevada Mountains, approximately 400 species of vertebrates are dependent on riparian areas for a portion of their life cycle (Kattelmann and Embury 1996). In Colorado, it is estimated that riparian areas, which account for only 1% of the landscape, are used by greater than 70% of the state's wildlife species and that 27% of the breeding bird species depend on riparian habitats for their viability (Knopf 1988; Pague and Carter 1996). Due to the more confined setting of riparian woodlands, this system may offer less habitat that other riparian areas, although they still are important for deer, moose, and elk as well as migratory birds and native cutthroat trout (Foster 1986). Open water areas such as beaver ponds provide nesting, feeding, and resting habitat for migrating waterbirds (Foster 1986). Small mammals such as meadow voles (*Microtus pennsylvanicus*), pocker gophers (*Thomomys talpoides*), field mice (*Permyscus* spp.), shrews (*Sorex* spp.), mink (*Mustela vison*), and ground squirrels (*Citellus* spp.) may use riparian woodlands that are seasonally wet (Foster 1986).

▪ A.2.3. Dynamics

Riparian Woodland development is driven mostly by magnitude and frequency of flooding, valley type, and stand replacing disturbances such as crownfire, disease, windthrow, or clearcutting by humans or beaver. Valley type may be the most important variable, as Riparian Woodlands are mostly found in V-shaped, steep valleys with many large boulders and coarse soils in the Southern Rocky Mountain region. The forest vegetation of Riparian Woodlands is often very similar to the adjacent uplands (Baker 1987, Windell et al. 1986). Some trees such as blue spruce (*Picea pungens*) show an affinity to riparian areas, while others have a broader tolerance of habitat. Disturbances may create gaps in the canopy and allow pioneer species, such as aspen, or shrubs to establish. For example, thinleaf alder (*Alnus incana*), Drummond's willow (*Salix drummondiana*), and red-osier dogwood (*Cornus sericea*) can dominant on steep and/or gravelly streams. Although these species can and do grow under the shade of the coniferous canopy, they seem to be most abundant along the streambanks of those stream wide enough to allow for abundant light penetration or where gaps in canopy have been created.

As mentioned above, beavers are not common in riparian woodlands due to their steep nature; however, since they can occur in some aspen types, their role in ecosystem development is discussed here. Beavers inhabit streams with a gentle gradient (< 15%) and in wide valleys (at least wider than the stream channel) (Bierly 1972). Beaver dams impound surface water creating open water areas. When dams are initially created, they often flood and kill large areas of shrublands. These areas are eventually colonized by emergent and submergent herbaceous vegetation. Depending on the duration of saturation and flooding, these vegetation types are considered marshes or wet meadows. As local food supplies are diminished, beavers tend to abandon their dams and move up or downstream to find additional food supply as well as suitable dam sites (Baker 1987; Phillips 1977). The abandoned beaver ponds eventually fill with sediment and are colonized by willows and tree saplings, thus completing the cycle. The presence of beaver creates a heterogeneous complex of wet meadows, marshes and riparian shrublands and increases species richness on the landscape. For example, Wright et al. (2002) note that beaver-modified areas may contribute as much as 25% of the species richness of herbaceous species in Adirondack Mountains of New York. Naiman et al. (1986) note that beaver-influenced streams are very different from those not impacted by beaver activity by having numerous zones of open water and vegetation, large accumulations of detritus and nutrients, more wetland areas, more anaerobic biogeochemical cycles, and in general are more resistance to disturbance. Neff (1957; *in* Knight 1994) estimated that a Colorado valley with an active beaver colony had eighteen times more water storage in the spring and an ability to support higher streamflow in late summer than a drainage where beaver were removed.

It is not known what the density of beaver were in the Southern Rocky Mountains prior to the fur trade (Baker 1987); however, Naiman et al. (1986) suggest that when beaver are not managed or harvested their activity may influence 20-40% of the total length of 2^{nd} to 5^{th} order streams in the boreal forest of Canada. It is apparent that active beaver colonies are very important for ecosystem development in riparian areas.

- ### A.2.4. Landscape

It is evident from the hydro-geomorphic setting of riparian woodlands that their integrity is partly determined by processes operating in the surrounding landscape and more specifically in the contributing watershed. The quality and quantity of surface water input into riparian woodlands is almost entirely determined by the condition of the surrounding landscape. Various types of land use can alter surface runoff, recharge of local aquifers, and introduce excess nutrients, pollutants, or sediments.

Riparian areas are intimately connected to uplands in their upstream watersheds as well as adjacent areas. However, the reverse is also true: riparian areas provide connectivity between upland systems and between up and downstream riparian patch types (Wiens 2002). Thus, the types, abundance, and spatial distribution of riparian patch types is an important ecological component to these systems as they affect the flow and movement of nutrients, water, seed dispersal, and animal movement (Wiens 2002).

Assessments of riparian woodlands assessing condition have considered the landscape properties of the local watershed to be a critical factor in assessing condition (Hauer et al. 2002, Hauer and Smith 1998, Costick 1996, Moyle and Randall 1998, Richter et al. 1997, Poff et al. 1997, and Rondeau 2001).

▪ A.2.5. Size

The size of a wetland or riparian area, whether very small or very large, is a natural characteristic defined by a site's topography, soils, and hydrological processes. The natural range of sizes found on the landscape varies for each wetland type. As long as a wetland has not been reduced in size by human impacts or isn't surrounded by areas which have experienced human disturbances, then size isn't very important to the assessment of ecological integrity. However, if human disturbances have decreased the size of the wetland or if the surrounding landscape is impacted and has the potential to affect the wetland, larger sized wetlands and riparian areas are able to buffer against these impacts better than smaller sized wetlands and riparian areas due to the fact they generally possess a higher diversity of abiotic and biotic processes allowing them to recover and remain more resilient. Under such circumstances, size may be an important factor in assessing ecological integrity.

Size is often very important when the conservation or functional value of a wetland is considered. For example, larger wetlands and riparian areas tend to have more diversity, often support larger populations of component species, are more likely to support sparsely distributed species, and may provide more suitable wildlife habitat as well as more ecological services derived from natural ecological processes (e.g. sediment/nutrient retention, floodwater storage, etc.) than smaller wetlands and riparian areas. Thus, when conservation or functional values are of concern, size is almost always an important component to the assessment.

Of course, in the context of regulatory wetland mitigation, size is always important whether mitigation transactions are based on function or integrity "units" and thus should be used to weight such transactions.

The size of riparian shrublands can vary greatly depending on their topographic location, underlying soil texture, and driving hydrological processes. Some are very small (> 8 linear km) while others can be very large (< 1.5 linear km).

A.3 ECOLOGICAL INTEGRITY

- ### A.3.1. Threats

Hydrological Alteration: Reservoirs, water diversions, ditches, roads, and human land uses in the contributing watershed can have a substantial impact on the hydrology as well as biotic integrity of riparian woodlands (Woods 2001; Kattelmann and Embury 1996; Poff et al. 1997; Baker 1987). All these stressors can induce downstream erosion and channelization, reduce changes in channel morphology, reduce base and/or peak flows, lower water tables in floodplains, and reduce sediment deposition in the floodplain (Poff et al. 1997). Vegetation responds to these changes by shifting from wetland and riparian dependent species to more mesic and xeric species typical of adjacent uplands (typical of herbaceous species) and/or encroaching into the stream channel. Although already narrow, floodplain width and the abundance and spatial distribution of various patch types also typically decline.

An unaltered hydrologic regime is crucial to maintaining the diversity and viability of the riparian area.

Land Use
Livestock management can impact riparian wooodlans by altering nutrient concentrations and cycles, changing surface and subsurface water movement and infiltration, shifting species composition, and reducing regeneration of woody species (Kauffman and Krueger 1984; Elmore and Kauffman 1984; Weixelman et al. 1997; Flenniken et al. 2001; Kauffman et al. 2004). Land use in adjacent uplands can affect hillslope runoff processes (Cooper 1990).

Nutrient enrichment: Adjacent and upstream land uses all have the potential to contribute excess nutrients into riparian areas. Increased nutrients can alter species composition by allowing aggressive, invasive species to displace native species.

Exotics: Fortunately, no non-native shrubs or trees occur in subalpine and montane riparian woodlands; however, there are numerous non-native herbaceous species which occur in disturbed riparian woodlands (Baker 1987). Such species include pasture grasses such as Kentucky bluegrass (*Poa pratensis*), orchard grass (*Dactylis glomerata*), and timothy (*Phleum pratense*) as well as exotics species common to other wetland types such as Canada thistle (*Cirsium arvense*) and dandelion (*Taraxacum officinale*).

Fragmentation: Human land uses both within the riparian area as well as in adjacent and upland areas can fragment the landscape and thereby reduce connectivity between riparian patches and between riparian and upland areas. This can adversely affect the movement of surface/groundwater, nutrients, and dispersal of plants and animals. Roads, bridges, and development can also fragment both riparian and upland areas. Intensive grazing and recreation can also create barriers to ecological processes.

A.3.2. Justification of Metrics

As reviewed above, the literature suggests that the following attributes are important measures of the ecological integrity of Rocky Mountain Subalpine-Montane Riparian Shrublands:

- Landscape Context: Land use within the contributing watershed and riparian corridor has important effects on the connectivity and sustainability of many ecological processes critical to this system.
- Biotic condition: Species composition and diversity, presence of conservative plants, regeneration, and invasion of exotics are important measures of biological integrity.
- Abiotic Condition: Hydrological integrity is the most important variable to measure, however land use within the wetland can have detrimental impacts on other important abiotic processes such as nutrient cycling, bank stability, and floodplain interaction.
- Size: Absolute size is important for consideration of conservation values as well as ecosystem resilience. Relative size is also very important as it provides information regarding historical loss or degradation of wetland size.

A.3.3. Ecological Integrity Metrics

A synopsis of the ecological metrics and ratings is presented in Table 2. The three tiers refer to levels of intensity of sampling required to document a metric. Tier 1 metrics are able to be assessed using remote sensing imagery, such as satellite or aerial photos. Tier 2 typically require some kind of ground sampling, but may require only qualitative or semi-quantitative data. Tier 3 metrics typically require a more intensive plot sampling or other intensive sampling approach. A given measure could be assessed at multiple tiers, though some metrics are not doable at Tier 1 (i.e., they require a ground visit).

Core and Supplementary Metrics

The Scorecard (see Tables 1 & 2) contains two types of metrics: Core and Supplementary. Separating the metrics into these two categories allows the user to adjust the Scorecard to available resources, such as time and funding, as well as providing a mechanism to tailor the Scorecard to specific information needs of the user.

Core metrics are shaded gray in Tables 1 & 2 and represent the minimal metrics that should be applied to assess ecological integrity. Sometimes, a Tier 3 Core metric might be used to replace Tier 2 Core Metrics. For example, if a Vegetation Index of Biotic Integrity is used, then it would not be necessary to use similar Tier 2 Core metrics such as Percentage of Native Graminoids, Percentage of Native Plants, etc.

Supplementary metrics are those which should be applied if available resources allow a more in depth assessment or if these metrics add desired information to the assessment. Supplementary metrics are those which are not shaded in Tables 1 & 2.

Table 1. Overall Set of Metrics for the Rocky Mountain Subalpine-Montane Riparian Woodland System. Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. (Alpha-numeric codes in parentheses refer to the metric ID and correspond to the section in which the metric is described). Shading indicates core metrics.

Category	**Essential Ecological Attribute**	**Indicators /Metrics**	**Tier**	**Field Value**	**Rating (E,G,F,P)**
LANDSCAPE CONTEXT	Landscape Composition	Adjacent Land Use (B.1.1)	1		
		Buffer Width (B.1.2)	1		
		Percentage of unfragmented landscape within 1 km. (B.1.3)	1		
		Riparian Corridor Continuity (B.1.4)	1		
BIOTIC CONDITION	Community Composition	Species Richness of Native Plants (B.2.1)	2		
		Percent of Cover of Native Plant Species (B.2.2)	2		
		Floristic Quality Index (Mean C) (B.2.3)	3		
	Patch Diversity	Biotic Patch Richness (B.2.4)	2		
		Interspersion of Biotic Patches (B.2.5)	2		
ABIOTIC CONDITION	Energy/ Material Flow	Land Use Within the Wetland (B.3.1)	1		
		Sediment Loading Index (B.3.2)	1		
	Hydrological Regime	Upstream Surface Water Retention (B.3.3)	1		

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Field Value	Rating (E,G,F,P)
		Upstream/Onsite Water Diversions (B.3.4)	1		
		Surface Water Runoff Index (B.3.5)	1		
		Index of Hydrological Alteration (B.3.6) NOTE: this metric should be used in lieu of B.3.3, B.3.4, B.3.5 and B.3.7 when data are available.	3		
		Bank Stability (B.3.7)	2		
	Chemical /Physical Processes	Litter Cover (B.3.8)	2		
		Nutrient/ Pollutant Loading Index (B.3.9)	1		
		Nitrogen Enrichment (C:N) (B.3.10)	3		
		Phosphorous Enrichment (C:P) (B.3.11)	3		
		Soil Organic Matter Decomposition (B.3.12)	2		
		Soil Organic Carbon (B.3.13)	3		
		Soil Bulk Density (B.3.14)	3		
SIZE	Absolute Size	Absolute Size (B.4.1)	1		
	Relative Size	Relative Size (B.4.2)	1		

Table 2. Metrics and Rating Criteria for the Rocky Mountain Subalpine-Montane Riparian Woodland System. Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. (Alpha-numeric codes in parentheses refer to the metric ID and correspond to the section in which the metric is described). Confidence column indicates that reasonable logic and/or data support the index.

Category	**Essential Ecological Attribute**	**Indicators /Metrics**	**Tier**	**Definition**	**Confidence**	*Metric Rating Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
LANDSCAPE CONTEXT	Landscape Composition	Adjacent Land Use (B.1.1)	1	Addresses the intensity of human dominated land uses within 100 m of the wetland.	Medium	Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4
		Buffer Width (B.1.2)	1	Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland.	Medium/High	Wide > 100 m	Medium. 50 m to <100 m	Narrow. 25 m to 50 m	Very Narrow. < 25 m
	Landscape Pattern	Percentage of unfragmented landscape within 1 km. (B.1.3)	1	An unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems.	Medium	Embedded in 90-100% unfragmented, roadless natural landscape; internal fragmentation absent	Embedded in 60-90% unfragmented natural landscape; internal fragmentation minimal	Embedded in 20-60%% unfragmented natural landscape; Internal fragmentation moderate	Embedded in < 20% unfragmented natural landscape. Internal fragmentation high
		Riparian Corridor Continuity (B.1.4)	1	Indicates the degree to which the riparian area exhibits an uninterrupted vegetated riparian corridor.	Medium/High	< 5% of riparian reach with gaps / breaks due to cultural alteration	> 5 - 20% of riparian reach with gaps / breaks due to cultural alteration	>20 - 50% of riparian reach with gaps / breaks due to cultural alteration	> 50% of riparian reach with gaps / breaks due to cultural alteration

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	Confidence	*Metric Rating Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
BIOTIC CONDITION	Community Composition	Species Richness of Native Plants (B.2.1)	2	Indicates the degree to which the riparian area supports the natural range of native plant richness.	Medium	Total Species Richness falls within the natural range of variability	Total Species Richness is less than Reference Range by at least 5 species	Total Species Richness is less than Reference Range by 5-10 species	Total Species Richness is less than Reference Range by > 10 species
		Percent of Cover of Native Plant Species (B.2.2)	2	Percent of the plant species which are native to the Southern Rocky Mountains.	High	100% cover of native plant species	85-< 100% cover of native plant species	50-85% cover of native plant species	<50% cover of native plant species
		Floristic Quality Index (Mean C) (B.2.3)	3	The mean conservatism of all the native species growing in the wetland.	High	Mean C > 4.5	Mean C = 3.5-4.5	Mean C = 3.0 – 3.5	Mean C < 3.0
	Community Extent	Biotic/Abiotic Patch Richness (B.2.4)	2	The number of biotic/abiotic patches or habitat types present in the wetland.	Medium	> 75-100% of the possible patch types are evident in the wetland	> 50-75% of the possible patch types are evident in the wetland	25-50% of the possible patch types are evident in the wetland	< 25% of the possible patch types are evident in the wetland
		Interspersion of Biotic Patches (B.2.5)	2	The spatial arrangement of biotic/abiotic patch types within the wetland, especially the degree to which patch types intermingle with each other (e.g. the amount of edge between patches).	Medium	Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a simple array of nested or interspersed biotic/abiotic patches,	Horizontal structure consists of one dominant patch type and thus has relatively no interspersion

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	Confidence	*Metric Rating Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
ABIOTIC CONDITION	Energy/ Material Flow	Land Use Within the Wetland (B.3.1)	1	Addresses the intensity of human dominated land uses within the wetland.	Medium	Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4
		Sediment Loading Index (B.3.2)	1	A measure of the varying degrees to which different land uses contribute excess sediment via surface water runoff and overland flow into a wetland.	Medium	Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7
	Pattern of Surface Flow	Upstream Surface Water Retention (B.3.3)	1	Measures the percentage of the contributing watershed which drains into water storage facilities capable of storing surface water from several days to months	Medium	< 5% of drainage basin drains to surface water storage facilities	>5 - 20% of drainage basin drains to surface water storage facilities	>20 - 50% of drainage basin drains to surface water storage facilities	> 50% of drainage basin drains to surface water storage facilities

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	Confidence	*Metric Rating Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
		Upstream/Onsite Water Diversions (B.3.4)	1	Measures the number of water diversions and their impact in the contributing watershed and in the wetland.	Low/Medium	No upstream or onsite water diversions present upstream of the riparian area	Few diversions present upstream of the riparian area relative to contributing watershed size. Onsite diversions, if present, do not appear to have only minor impact on local hydrology.	Many diversions present upstream of the riparian area relative to contributing watershed size. Onsite diversions, if present, appear to have a major impact on local hydrology.	Water diversions are very numerous upstream of the riparian area relative to contributing watershed size. Onsite diversions, if present, have drastically altered local hydrology.
	Pattern of Surface Flows	Surface Water Runoff Index (B.3.5)	1	A measure of the varying degrees to which different land uses alters surface water runoff and overland flow into a wetland.	Medium	Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7
	NOTE: this metric should be used in lieu of B.3.3, B.3.4, B.3.5 and B.3.7 when data are available.	Index of Hydrological Alteration (B.3.6)	3	Uses daily streamflow data to determine trends at one site or determine differences between pre- and post-impacts of sites.	Medium/High	No significant change from Reference Hydrographs	Slight change from Reference Hydrographs	Moderate change from Reference Hydrographs	Large change from Reference Hydrographs

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	Confidence	*Metric Rating Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
		Bank Stability (B.3.7)	2	Assesses the stability and condition of the streambanks.	Medium	Banks stable; evidence of erosion of bank failure absent or minimal; little potential for future problems. < 5% of bank affected. Streambanks dominated (> 90% cover) by Stabilizing Plant Species (OBL & FACW)	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion. Streambanks have 75-90% cover of Stabilizing Plant Species (OBL & FACW)	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods. Streambanks have 60-75% cover of Stabilizing Plant Species (OBL & FACW)	Unstable; many eroded areas; "raw" AREAS frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars. Streambanks have < 60% cover of Stabilizing Plant Species (OBL & FACW)
	Nutrient Cycling	Litter Cover (B.3.8)	2	The percent cover of plant litter or detritus covering the soil surface.	Low/Medium	Litter cover 75-125% of Reference Standard (Litter > 50% cover)	Litter cover 25-75% of Reference Standard (Litter 10-50% cover)	Litter cover 0-25% of Reference Standard (Litter cover present but sparse < 10%)	No litter present.
	Nutrient Enrichment	Nutrient/ Pollutant Loading Index (B.3.9)	1	A measure of the varying degrees to which different land uses contributed excess nutrients and pollutants via surface water runoff and overland flow into a wetland.	Medium	Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	Confidence	*Metric Rating Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
		Nitrogen Enrichment (C:N) (B.3.10)	3	The carbon to nitrogen (C:N) ratio in the aboveground biomass or leaves of plants. .	Medium/High	Leaf tissue C:N is equivalent to natural range of variability	Leaf tissue C:N is slightly less and outside of natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability
		Phosphorous Enrichment (C:P) (B.3.11)	3	The carbon to phosphorous (C:P) ratio in the aboveground biomass or leaves of plants.	Medium/High	Leaf tissue C:P is equivalent to natural range of variability	Leaf tissue C:P is slightly less and outside of natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability
	Organic matter	Soil Organic Matter Decomposition (B.3.12)	2	The metric is calculated as an Organic Matter Decomposition Factor (OMDF) based on the depth of the O-horizon, the depth and soil color value of the surface-horizons.	Medium	OMDF > 4.75	OMDF 3.0 - 4.75	OMDF 1.25 - 3.0	OMDF < 1.25
		Soil Organic Carbon (B.3.13)	3	Measures the amount of soil organic carbon present in the soil.	Medium/High	Soil C is equivalent to natural range of variability	Soil C is nearly equivalent to natural range of variability	Soil C is significantly lower than natural range of variability	Soil C is significantly lower than natural range of variability
	Compaction	Soil Bulk Density (B.3.14)	3	A measure of the compaction of the soil horizons.	Medium/High	Bulk density is within natural range of variability	Bulk density is slightly higher than natural range of variability	Bulk density is higher than natural range of variability	Bulk density is much higher than natural range of variability
SIZE	Absolute Size	Absolute Size (B.4.1)	1	The current size of the wetland	High	> 8.0 linear km (minimum of 10 m wide)	5.0 to 8.0 linear km (minimum of 10 m wide)	1.5 to 5.0 linear km (minimum of 10 m wide)	< 1.5 linear km (minimum of 10 m wide)

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	Confidence	*Metric Rating Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
	Relative Size	Relative Size (B.4.2)	1	The current size of the wetland divided by the total potential size of the wetland multiplied by 100.	High	Wetland area = onsite Abiotic Potential	Wetland area < Abiotic Potential; Relative Size = 90 – 100% ; (< 10% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc.	Wetland area < Abiotic Potential; Relative Size = 75 – 90%; 10-25% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc	Wetland area < Abiotic Potential; Relative Size = < 75%; > 25% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc

A.4 Scorecard Protocols

For each metric, a rating is developed and scored as A – (Excellent) to D – (Poor). The background, methods, and rationale for each metric are provided in section B. Each metric is rated, then various metrics are rolled together into one of four categories: Landscape Context, Biotic Condition, Abiotic Condition, and Size. A point-based approach is used to roll-up the various metrics into Category Scores.

Points are assigned for each rating level (A, B, C, D) within a metric. The default set of points are A = 5.0, B = 4.0, C = 3.0, D = 1.0. Sometimes, within a category, one measure is judged to be more important than the other(s). For such cases, each metric will be weighted according to its perceived importance. Points for the various measures are then added up and divided by the total number of metrics. The resulting score is used to assign an A-D rating for the category. After adjusting for importance, the Category scores could then be averaged to arrive at an Overall Ecological Integrity Score.

Supplementary metrics are not included in the Rating Protocol. However, they could be incorporated if the user desired.

- #### A.4.1. Landscape Context Rating Protocol

Rate the Landscape Context metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 3) to roll up the metrics into an overall Landscape Context rating.

<u>Rationale for Scoring:</u> Adjacent land use, buffer width, and connectivity of the riparian corridor are judged to be more important than the amount of fragmentation within 1 km of the wetland since a wetland with no other natural communities bordering it is very unlikely to have a strong biological connection to other natural lands at a further distance.

Thus, the following weights apply to the Landscape Context metrics:

Table 3. Landscape Context Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight	Score (weight x rating)
Adjacent Land Use (B.1.1)	Addresses the intensity of human dominated land uses within 100 m of the wetland.	1	5	4	3	1	0.30	
Buffer Width (B.1.2)	Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland.	1	5	4	3	1	0.30	
Percentage of unfragmented landscape within 1 km. (B.1.3)	An unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems.	1	5	4	3	1	0.10	
Riparian Corridor Continuity (B.1.4)	Indicates the degree to which the riparian area exhibits an uninterrupted vegetated riparian corridor.	1	5	4	3	1	0.30	
Landscape Context Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

- **A.4.2. Biotic Condition Rating Protocol**

Rate the Biotic Condition metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 4) to roll up the metrics into an overall Biotic Condition rating.

Rationale for Scoring: The Floristic Quality Index (FQI) metric is judged to be more important than cover of native species and invasive species metric. The latter two provide very useful information, but the FQI provides a more reliable indicator of biotic condition.

Scoring for Biotic Condition is a bit more complex. For example, the Floristic Quality Index (FQI) may or may not be assessed, depending on resources (since it is a Tier 3 metric). If it is included then the weights without parentheses apply to the Biotic Condition metrics. If FQI is not included, then the weight in parentheses is used for the Tier 2 metrics.

Table 4. Biotic Condition Rating Calculation.

Measure	**Definition**	**Tier**	**A**	**B**	**C**	**D**	**Weight***	**Score** (weight x rating)
Species Richness of Native Plants (B.2.1)	Indicates the degree to which the riparian area supports the natural range of native plant richness.	2	5	4	3	1	0.25 (0.50)	
Percent of Cover of Native Plant Species (B.2.2)	Percent of the plant species which are native to the Southern Rocky Mountains.	2	5	4	3	1	0.25 (0.50)	
Floristic Quality Index (Mean C) (B.2.3)	The mean conservatism of all the native species growing in the wetland.	3	5	4	3	1	0.50 (N/A)	
Biotic Condition Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when metric B.2.3 is not used.

- **A.4.3 Abiotic Condition Rating Protocol**

Rate the Abiotic Condition metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 5) to roll up the metrics into an overall Abiotic Condition rating.

Rationale for Scoring: Quantitative water table data are judged to more reliable than the other metrics for indicating Abiotic Condition (shaded metric in Table 5). However, if such data are lacking then stressor related metrics (Land Use & Hydrological Alterations) are perceived to provide more dependable information concerning Abiotic Condition.

Table 5. Abiotic Condition Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Land Use Within the Wetland (B.3.1)	Addresses the intensity of human dominated land uses within the wetland.	1	5	4	3	1	0.25	
Upstream Surface Water Retention (B.3.3)	Measures the percentage of the contributing watershed which drains into water storage facilities capable of storing surface water from several days to months	1	5	4	3	1	0.25	
Upstream/Onsite Water Diversions (B.3.4)	Measures the number of water diversions and their impact in the contributing watershed and in the wetland.	1	5	5	0	0	0.25	
Bank Stability (B.3.7)	Assesses the stability and condition of the streambanks.	2	5	4	3	1	0.25	
Index of Hydrological Alteration (B.3.6)	Uses daily streamflow data to determine trends at one site or determine differences between pre- and post-impacts of sites.	3					N/A *1.0*	
Abiotic Condition Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

* B.3.6is a more accurate and reliable measure than the other metrics. Thus, if B.3.6 is used no other metrics are needed for the assessment.

- **A.4.4 Size Rating Protocol**

Rate the two measures according to the metrics protocols (see Table 2 and details in Section B). Use the scoring table below (Table 6) to roll up the metrics into an overall Size rating.

<u>Rationale for Scoring</u>: Since the importance of size is contingent on human disturbance both within and adjacent to the wetland, two scenarios are used to calculate size:

(1) When Landscape Context Rating = "A":
Size Rating = Relative Size metric rating (weights w/o parentheses)

(2) When Landscape Context Rating = "B, C, or D".
Size Rating = (weights in parentheses)

Table 6. Size Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Absolute Size (B.4.1)	The current size of the wetland	1	5	4	3	1	0.0 (0.70)	
Relative Size (B.4.2)	The current size of the wetland divided by the total potential size of the wetland multiplied by 100.	1	5	4	3	1	1.0 (0.30)	
Size Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when Landscape Context Rating = B, C, or D.

A.4.5 Overall Ecological Integrity Rating Protocol

If an Overall Ecological Integrity Score is desired for a site, then a weighted-point system should be used with the following rules:

1. If Landscape Context = *A* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.25)] + [Size Score * (0.15)]** **Note:** For this calculation ONLY consider Relative Size for Size Score

2. If Landscape Context is *B*, *C*, or *D* AND Size = *A* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Size Score * (0.25)] + [Landscape Context Score * (0.15)]**

3. If Landscape Context is *B*, *C*, or *D* AND Size = *B* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.20)] + [Size Score * (0.20)]**

4. If Landscape Context is *B*, *C*, or *D* AND Size = *C* or *D* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.25)] + [Size Score * (0.15)]** **Note:** For this calculation use both Absolute and Relative Size for Size Score.

The Overall Ecological Rating is then assigned using the following criteria:

A = 4.5 - 5.0
B = 3.5 – 4.4
C = 2.5 – 3.4
D = 1.0 – 2.4

B. PROTOCOL DOCUMENTATION FOR METRICS

B.1 Landscape Context Metrics

▪ B.1.1. Adjacent Land Use

Definition: This metric addresses the intensity of human dominated land uses within 100 m of the wetland.

Background: This metric is one aspect of the landscape context of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: The intensity of human activity in the landscape has a proportionate impact on the ecological processes of natural systems. Each land use type occurring in the 100 m buffer is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the wetland (Hauer et al. 2002).

Measurement Protocol: This metric is measured by documenting surrounding land use(s) within 100 m of the wetland. This should be completed in the field then verified in the office using aerial photographs or GIS. However, with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within 100 m of the wetland edge.

To calculate a Total Land Use Score estimate the % of the adjacent area within 100 m under each Land Use type and then plug the corresponding coefficient (Table 3) with some manipulation to account for regional application) into the following equation:

> *Sub-land use score* = ∑ LU x PC/100
>
> where**:** LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type.

Do this for each land use within 100 m of the wetland edge, then sum the Sub-Land Use Score(s) to arrive at a Total Land Score. For example, if 30% of the adjacent area was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4

Data:

Table 7. Current Land Use and Corresponding Land Use Coefficients (based on Table 21 in Hauer et al. (2002))

Current Land Use	Coefficient
Paved roads/parking lots/domestic or commercially developed buildings/gravel pit operation	0.0
Unpaved Roads (e.g., driveway, tractor trail) / Mining	0.1
Agriculture (tilled crop production)	0.2
Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.)	0.3
Logging or tree removal with 50-75% of trees >50 cm dbh removed	0.4
Hayed	0.5
Moderate grazing	0.6
Moderate recreation (high-use trail)	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing / light recreation (low-use trail)	0.9
Fallow with no history of grazing or other human use in past 10 yrs	0.95
Natural area / land managed for native vegetation	1.0

Scaling Rationale: Land uses have differing degrees of potential impact. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter hydrological processes. The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002).

Confidence that reasonable logic and/or data support the index: Medium.

- ### B.1.2. Buffer Width

Definition: Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland. This includes forests, grasslands, shrublands, lakes, ponds, streams, or another wetland.

Background: This metric is one aspect of the landscape context of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. Buffers reduce potential impacts to wetlands and riparian areas by alleviating the effects of adjacent human activities (Castelle et al. 1992). For example, buffers can moderate stormwater runoff, reduce loading of sediments, nutrients, and pollutants into a wetland as well as provide habitat for wetland-associated species for use in feeding, roosting, breeding and cover (Castelle et al. 1992).

Measurement Protocol: This metric is measured by estimating the width of the buffer surrounding the wetland. Buffer boundaries extend from the wetland edge to intensive human land uses which result non-natural areas. Some land uses such as light grazing and recreation may occur in the buffer, but other more intense land uses should be considered the buffer boundary. Irrigated meadows may be considered a buffer if the area appears to function as a buffer between the wetland and nearby, more intensive land uses such as agricultural row cropping, fenced or unfenced pastures, paved areas, housing developments, golf courses, mowed or highly managed parkland, mining or construction sites, etc. (Mack 2001).

Measurement should be completed in the field then verified in the office using aerial photographs or GIS. Measure or estimate buffer width on four or more sides of the wetland then take the average of those readings (Mack 2001). This may be difficult for large wetlands and riparian areas or those with complex boundaries. For such cases, the overall buffer width should be estimated using best scientific judgment.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Wide > 100 m	Medium. 50 m to <100 m	Narrow. 25 m to 50 m	Very Narrow. < 25m

Data: N/A

Scaling Rationale: Increases in buffer width improve the effectiveness of the buffer in moderating excess inputs of sediments, nutrients, and other pollutants from surface water runoff and provides more potential habitat for wetland dependent species (Castelle et al. 1992). The categorical ratings are based on data from Castelle et al. (1992), Keate (2005), Mack (2001), and best scientific judgment regarding buffer widths and their effectiveness in the Southern Rocky Mountains.

Confidence that reasonable logic and/or data support the index: Medium/High.

- ### B.1.3. Percentage of Unfragmented Landscape Within One Kilometer

Definition: An unfragmented landscape is one in which human activity has not destroyed or severely altered the landscape. In other words, an unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems. Fragmentation results from human activities such as timber clearcuts, roads, residential and commercial development, agriculture, mining, utility lines, railroads, etc.

Background: This metric is one aspect of the landscape context of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. The percentage of fragmentation (e.g., anthropogenic patches) provides an estimate of connectivity among natural ecological systems. Although related to metric B.1.1 and B.1.2, this metric differs by addressing the spatial interspersion of human land use as well as considering a much larger area.

Measurement Protocol: This metric is measured by estimating the amount of unfragmented area in a one km buffer surrounding the wetland and dividing that by the total area. This can be completed in the office using aerial photographs or GIS.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Embedded in 90-100% unfragmented, roadless natural landscape; internal fragmentation absent	Embedded in 60-90% unfragmented natural landscape; internal fragmentation minimal	Embedded in 20-60%% unfragmented natural landscape; Internal fragmentation moderate	Embedded in < 20% unfragmented natural landscape. Internal fragmentation high

Data: N/A

Scaling Rationale: Less fragmentation increases connectivity between natural ecological systems and thus allow for natural exchange of species, nutrients, and water. The categorical ratings are based on Rondeau (2001).

Confidence that reasonable logic and/or data support the index: Medium.

- ### B.1.4. Riparian Corridor Continuity

Definition: This metric indicates the degree to which the riparian area exhibits an uninterrupted naturally vegetated riparian corridor.

Background: This metric is one aspect of the landscape context of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Riparian areas are typically comprised of a continuous corridor of intact natural vegetation along the stream channel and floodplain (Smith 2000). These corridors allow uninterrupted movement of animals to up- and down-stream portions of the riparian zone as well as access to adjacent uplands (Gregory et al. 1991). These corridors also allow for unimpeded movement of surface and overbank flow, which are critical for the distribution of sediments and nutrients as well as recharging local alluvial aquifers. Fragmentation of the riparian corridor can occur as a result of human alterations such as roads, power and pipeline corridors, agriculture activities, and urban/industrial development (Smith 2000).

Measurement Protocol: This metric is measured as the percent of anthropogenic patches within the riparian corridor. Anthropogenic patches are defined as areas which have been converted or are dominated by human activities such as heavily grazed pastures, roads, bridges, urban/industrial development, agriculture fields, and utility right-of-ways. The riparian corridor itself is defined at the width of the geomorphic floodplain. Using GIS, field observations, and/or aerial photographs the area occupied by anthropogenic patches is compare to the area occupied by natural vegetation with the riparian corridor.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
< 5% of riparian reach with gaps / breaks due to cultural alteration	> 5 - 20% of riparian reach with gaps / breaks due to cultural alteration	>20 - 50% of riparian reach with gaps / breaks due to cultural alteration	> 50% of riparian reach with gaps / breaks due to cultural alteration

Data: N/A

Scaling Rationale: As fragmentation increases the continuity of natural vegetated patches in the riparian decreases, along with corresponding changes in species, sediment, nutrient, and water movement. The categorical ratings are based on Smith (2000).

Confidence that reasonable logic and/or data support the index: Medium/High.

B.2 Biotic Condition Metrics

- **B.2.1. Species Richness of Native Plants**

Definition: This metric indicates the degree to which the riparian area supports the natural range of native plant richness.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Productivity and spatial and temporal heterogeneity are underlying factors which strongly influence species diversity due to their affect on resource abundance and niche diversity (Vannote et al. 1980, Gregory et al. 1991; Manley and Schlesinger 2001). Although human disturbance can cause an increase in diversity, that shift is often associated with an increase in the amount of non-native species. Thus, the expected range of species richness of native plants in an area is assumed to be indicative of the natural range of variation in the environmental factors which control productivity and spatial heterogeneity in riparian shrublands. As native plant richness decreases, it is assumed that the underlying factors controlling diversity, mainly productivity and spatial heterogeneity, have been altered either from nutrient enrichment, invasive and/or non-native species, or other human-induced disturbances.

Measurement Protocol: A qualitative estimate of richness is used to calculate and score the metric. The entire occurrence of the riparian system should be walked and a comprehensive species list should be made. Alternatively, if time and resources allow a more quantitative determination of species presence and cover such methods (i.e. Peet et al. 1998) are encouraged to be used. The metric is calculated by totaling the number of native species in each of the following categories: Total native trees, shrubs, graminoids, forbs, and overall richness. These values are then compared to Table 8 to determine the metric status in the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Total Species Richness falls within the natural range of variability	Total Species Richness is less than Reference Range by at least 5 species	Total Species Richness is less than Reference Range by 5-10 species	Total Species Richness is less than Reference Range by > 10 species

Data: In Colorado, Baker (1990) found that species richness of native plants in undisturbed riparian shrublands is as follows:

Table 8. Floristic Richness Values for Riparian Woodlands

	Riparian Woodlands
Trees	Mean of 3.2 species/0.1 ha (range of 0-2)
Shrubs	Mean of 9.2 species/0.1 ha (range of 2-19)
Forbs	Mean of 35.2 species/0.1 ha (range of 2-51)
Graminoids	Mean of 10.2 species/0.1 ha (range of 2-20)
Total Species Richness	Mean of 57.8 species/0.1 ha (range of 39-87)

Scaling Rationale: These ratings are based on best scientific judgment. .

Confidence that reasonable logic and/or data support the index: Medium.

- **B.2.2. Percent of Cover of Native Plant Species**

Definition: Percent of the plant species which are native to the Southern Rocky Mountains.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Native species dominate Southern Rocky Mountain wetlands and riparian areas that have excellent ecological integrity. This metric is a measure of the degree to which native plant communities have been altered by human disturbance. With increasing human disturbance, non-native species invade and can dominate the wetland.

Measurement Protocol: A qualitative, ocular estimate of cover is used to calculate and score the metric. The entire occurrence of the riparian system should be walked and a qualitative ocular estimate of the total cover of native species growing in the wetland should be made. Alternatively, if time and resources allow a more quantitative determination of species presence and cover such methods (i.e. Peet et al. 1998) are encouraged to be used. The metric is calculated by dividing the total cover of native species by the total cover of all species and multiplying by 100.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
100% cover of native plant species	85-< 100% cover of native plant species	50-85% cover of native plant species	<50% cover of native plant species

Data: N/A

Scaling Rationale: The criteria are based on extrapolated thresholds from ecological site descriptions from Utah, Wyoming, and Montana (NRCS 2005), data and descriptions in Cooper (1990), Windell et al. (1996), CNHP (2005), and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data. The Colorado Natural Heritage Program is currently developing a Vegetation Index of Biotic Integrity. Data from this project will likely provide the necessary information to confirm, validate, and improve the criteria.

Confidence that reasonable logic and/or data support the index: High

▪ B.2.3. Floristic Quality Index (Mean C)

Definition: The mean conservatism of all the native species growing in the wetland.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Plants grow in habitats in which they are adapted to, including biotic and abiotic fluctuations associated with that habitat (Wilhelm and Masters 1995). However, when disturbances to that habitat exceed the natural range of variation (e.g. many human-induced disturbances), only those plants with wide ecological tolerance will survive and conservative species (e.g. those species with strong fidelity to habitat integrity) will decline or disappear according to the degree of human disturbance (Wilhelm and Master 1995; Wilhelm personal communication, 2005).

The Floristic Quality Index (FQI), originally developed for the Chicago region (Swink and Wilhelm 1979, 1994) is a plant community index designed to assess the degree of "naturalness" of an area based on the presence of species whose ecological tolerance are limited (U.S. EPA 2002). FQI methods have been developed and successfully tested in Illinois (Swink and Wilhelm 1979), Missouri (Ladd 1993), Ohio (Andreas and Lichvar

1995), southern Ontario (Oldham et al. 1995), Michigan (Herman et al. 1996), Indiana (Coffee Creek Watershed Conservancy, 2001), and North Dakota (Northern Great Plains Floristic Quality Assessment Panel, 2001).

The Colorado Floristic Quality Assessment Panel is currently assigning coefficients of conservatism to the Colorado flora. Initial testing of the Colorado FQI should begin in 2006 and available for use shortly thereafter. However, calibration of the FQI will likely occur over many years of use and thus this metric will need to be updated accordingly.

Mean C is

Measurement Protocol: Species presence/absence data need to be collected from the wetland. Although, quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the wetland system and make notes of each species encountered. A thorough search of each macro- and micro-habitat is required. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Mack 2004; Peet et al. 1998).

The metric is calculated by referencing only native species C value from the Colorado FQI Database (*in development*; *expected to be completed in 2006*), summing the C values, and dividing by the total number of native species (Mean C).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
> 4.5	3.5-4.5	3.0 – 3.5	< 3.0

Data: Colorado FQI Database (*in development*; *expected to be completed in 2006*)

Scaling Rationale: In the Midwest, field studies using FQI have determined that a site with a Mean C of 3.0 or less is unlikely to achieve higher C values; thus, this value was used as the Restoration Threshold (between Fair and Poor). In other words, those sites have been disturbed to the degree that conservative species are no longer able to survive and or compete with the less conservative species as a result of the changes to the soil and or hydrological processes on site (Wilhelm and Masters 1995). Sites with a Mean C of 3.5 or higher are considered to have at least marginal quality or integrity; thus, this value was used as the Minimum Integrity Threshold (between Good and Fair) (Wilhelm and Masters 1995). The threshold between Excellent and Good was assigned based on best scientific judgment upon reviewing the FQI literature. Although it is not know if these same thresholds are true for the Southern Rocky Mountains, they have been used to construct the scaling for this metric. As the FQI is applied in this region, the thresholds may change.

Confidence that reasonable logic and/or data support the index: High

▪ B.2.4. Biotic/Abiotic Patch Richness

Definition: The number of biotic/abiotic patches or habitat types present in the wetland. The metric is not a measure of the spatial arrangement of each patch.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Ecological diversity of a site is correlated with biotic/abiotic patch richness (Collins et al. 2004). Unimpacted sites have an expected range of biotic/abiotic patches. Human-induced alterations can decrease patch richness by homogenizing microtopography, altering channel characteristics, etc.

Measurement Protocol: This metric is measured by determining the number of biotic/abiotic patches present at a site and dividing by the total number of possible patches for the specific wetland (see Table 5). This percentage is then used to rate the metric in the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
> 75-100% of the possible patch types are evident in the AA	> 50-75% of the possible patch types are evident in the AA	25-50% of the possible patch types are evident in the AA	< 25% of the possible patch types are evident in the AA

Data:

Table 9. Biotic/Abiotic Patch Types in Riparian Woodlands

Patch Type
Open water –stream
Open water – beaver pond
Active beaver dams
Shrub canopy
Herbaceous canopy
Moss canopy
Adjacent hillside seeps/springs
Coniferous tree canopy
Deciduous canopy
Coniferous and deciduous mixed canopy
Streams – pool/riffle complex
Debris jams (woody debris) in stream
Submerged/floating vegetation
Emergent vegetation
TOTAL = 13

Scaling Rationale: The scaling criteria are based on Collins et al. (2004); however, best scientific judgment was used to modify patch types to correspond with Southern Rocky Mountain wetlands and riparian areas.

Confidence that reasonable logic and/or data support the index: Medium

- ### B.2.5. Interspersion of Biotic/Abiotic Patches

Definition: Interspersion is the spatial arrangement of biotic/abiotic patch types within the wetland, especially the degree to which patch types intermingle with each other (e.g. the amount of edge between patches).

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Spatial complexity of biotic/abiotic patches is indicative of intact ecological processes (Collins et al. 2004). Unimpacted sites have an expected spatial pattern of biotic/abiotic patches. Human-induced alterations can decrease this complexity and homogenize patch distribution.

Measurement Protocol: This metric is measured by determining the degree of interspersion of biotic/abiotic patches present in the wetland. This can be completed in the field for most wetlands and riparian areas, however aerial photography may be beneficial for larger sites (Collin et al. 2004). The metric is rated by matching site interspersion with the categorical ratings in the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a simple array of nested or interspersed biotic/abiotic patches,	Horizontal structure consists of one dominant patch type and thus has relatively no interspersion

Data: See B.2.4 for list and definitions of Biotic Patches.

Scaling Rationale: The scaling criteria are based on Collin et al. (2004), however best scientific judgment was used to modify criteria to correspond with Southern Rocky Mountain wetlands and riparian areas.

Confidence that reasonable logic and/or data support the index: Medium

B.3 Abiotic Condition Metrics

- #### B.3.1. Land Use Within the Wetland

Definition: This metric addresses the intensity of human dominated land uses within the wetland.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: The intensity of human activity in the wetland often has a proportionate impact on the ecological processes occurring onsite. Each land use type is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the wetland (Hauer et al. 2002).

Measurement Protocol: This metric is measured by documenting land use(s) within the wetland. This should be completed in the field then verified in the office using aerial photographs or GIS. However, with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within 100 m of the wetland edge.

To calculate a Total Land Use Score estimate the % of the wetland area under each Land Use type and then plug the corresponding coefficient (Table 6) with some manipulation to account for regional application) into the following equation:

$$\textit{Sub-land use score} = \sum \text{LU} \times \text{PC}/100$$

where**:** LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type.

Complete the calculation for each land use, then sum the Sub-Land Use Score(s) to arrive at a Total Land Score. For example, if 30% of the wetland was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4

Data:

Table 10. Current Land Use and Corresponding Land Use Coefficients (based on Table 21 in Hauer ete al. (2002))

Current Land Use	Coefficient
Paved roads/parking lots/domestic or commercially developed buildings/gravel pit operation	0.0
Unpaved Roads (e.g., driveway, tractor trail) / Mining	0.1
Agriculture (tilled crop production)	0.2
Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.)	0.3
Logging or tree removal with 50-75% of trees >50 cm dbh removed	0.4
Hayed	0.5
Moderate grazing	0.6
Moderate recreation (high-use trail)	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing / light recreation (low-use trail)	0.9
Fallow with no history of grazing or other human use in past 10 yrs	0.95
Natural area / land managed for native vegetation	1.0

Scaling Rationale: The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002). Land uses have differing degrees of potential impact. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement.

Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter hydrological processes.

Confidence that reasonable logic and/or data support the index: Medium.

- **B.3.2. Sediment Loading Index**

Definition: The sediment loading index is a measure of the varying degrees to which different land uses contribute excess sediment via surface water runoff and overland flow into a wetland.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: The type and amount of each land use in the wetland and contributing watershed affects the amount of sediment that enters into a wetland. Excess sediment can change nutrient cycling, bury vegetation, suppress regeneration of plants, and carry pollutants into the wetland.

In a functional assessment of slope and depressional wetlands associated with the Great Salt Lake, Keate (2005) developed a HGM assessment model primarily based on land use as a surrogate for human impacts on wetland functions. Coefficients from Nnadi (1997) were used to represent the sediment, nutrient loading, runoff, and wildlife impacts associated with various land uses. The functions considered included hydrologic, geochemical and habitat characteristics. The same coefficients used in the Keate (2005) method are used for this metric.

Measurement Protocol: Identify and estimate the percentage of each land use within the wetland and the contributing watershed (within 100 m of the wetland). This is best completed in the field, however with access to current aerial photography a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use. Once the percentage of each land use is identified, multiply it by the corresponding Sediment Loading coefficient found for each land use in Appendix B, then sum for the Sediment Loading Index Score.

For example, if 50% of the wetland and contributing watershed (within 100 m of the wetland) was multi-family residential, 20% had a dirt/local roads, and 30% natural vegetation the calculation would be (0.5 * 0.61) + (0.2 * 0.97) + (0.3* 1.0) = 0.79 (Sediment Loading Index Score). Referring to the scorecard, this would give the metric a "Fair" rating.

The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. Surface water divides are determined using topography and although groundwater divides do not always coincide with these same hydrological divides, groundwater movement is assumed to do so, unless other data for the site is available.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7

Data: Appendix B.

Scaling Rationale: The scaling is based on best scientific judgment. Scores below 0.7 are assumed to have crossed a threshold in which loading impacts are considered to not be restoreable (based on the land uses that have coefficients below 0.7). Additional research may suggest changes to the scaling criteria.

Confidence that reasonable logic and/or data support the index: Low/medium.

- ### B.3.3. Upstream Surface Water Retention

Definition: This metric measures the percentage of the contributing watershed which drains into water storage facilities (e.g., reservoirs, sediment basins, retention ponds, etc.) that are capable of storing surface water from several days to months (Smith 2000).

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Ecological processes of riparian areas are driven to a large degree by the magnitude and frequency of peak flows and the duration and volume of base flows (Poff et al. 1997). The biotic and physical integrity of riparian areas are dependent on the natural variation associated with these flow characteristics (Gregory et al. 1991; Poff et al. 1997). The amount of water retained in upstream facilities has a direct effect on these flows and subsequent effects on the continued biotic and physical integrity of the riparian area (Poff et al. 1997). For example, retention of surface water can decrease or eliminate episodic, high intensity flooding, decrease seasonal high flows (e.g., spring snowmelt) and increase base flows during seasonal dry periods causing a shift in channel morphology and altering the dispersal capabilities, germination, and survival of many plant species dependent on those flows (Poff et al. 1997; Patten 1998).

Measurement Protocol: This metric is measured as the percent of the contributing watershed to the riparian area that occurs upstream of a surface water retention facility. First the total area of the contributing watershed needs to be determined. Next, the area of the contributing watershed which is upstream of the surface water retention facility furthest downstream is calculated for each stream reach (e.g., main channel and/or tributaries) then summed, divided by the total area of the contributing watershed, then multiplied by 100 to arrive at the metric value. For example if a dam occurs on the main channel, then the entire watershed upstream of that dam is calculated whereas if only small dams occur on tributaries then the contributing watershed upstream of each dam on each of the tributaries would be calculated then summed.

These calculations can be conducted using GIS themes of surface water retention facilities, USGS 7.5 minute topographic maps, and/or Digital Elevation Models. The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. The percentage of the contributing watershed upstream of surface water retention facilities is simply "cut" from the original contributing watershed layer and its area is then calculated then compared to the total area.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
< 5% of drainage basin drains to surface water storage facilities	>5 - 20% of drainage basin drains to surface water storage facilities	>20 - 50% of drainage basin drains to surface water storage facilities	> 50% of drainage basin drains to surface water storage facilities

Data: A GIS layer of surface water retention facilities can be downloaded from the Colorado Division of Water Resource's Decision Support Systems website: http://cdss.state.co.us/

Scaling Rationale: The scaling is based on Smith (2000) and best scientific judgment. Additional research may suggest changes to the scaling criteria.

Confidence that reasonable logic and/or data support the index: Medium.

- ### B.3.4. Upstream/Onsite Water Diversions

Definition: This metric measures the number of water diversions and their impact in the contributing watershed and in the wetland relative to the size of the contributing watershed.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Ecological processes of riparian areas are driven to a large degree by the magnitude and frequency of peak flows and the duration and volume of base flows (Poff et al. 1997). The biotic and physical integrity of riparian areas are dependent on the natural variation associated with these flow characteristics (Gregory et al. 1991; Poff et al. 1997). The amount of water imported, exported, or diverted from a watershed can affect these processes by decreasing episodic, high intensity flooding, seasonal high flows (e.g., spring snowmelt), and base flows (Poff et al. 1997; Patten 1998).

Measurement Protocol: This metric can be measured by calculating the total number of water diversions occurring in the upstream contributing watershed as well as those onsite. The number of diversions relative to the size of the contributing basin is considered and then compared to the scorecard to determine the rating.

Since the riparian area may occur on a variety of stream orders and since the corresponding upstream or contributing watershed differs in area, it is difficult to set standard guidelines. Thus, the user must use their best scientific judgment regarding the number of diversions and their impact relative to the size of the contributing watershed. If available, attributes such as capacity (cubic feet/second) of each diversion can be considered in the assessment.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
No upstream or onsite water diversions present	Few diversions present or impacts from diversions minor relative to contributing watershed size. Onsite diversions, if present, appear to have only minor impact on local hydrology.	Many diversions present or impacts from diversions moderate relative to contributing watershed size. Onsite diversions, if present, appear to have a major impact on local hydrology.	Water diversions are very numerous or impacts from diversions high relative to contributing watershed size. Onsite diversions, if present, have drastically altered local hydrology.

Data: A GIS layer of surface water diversions can be downloaded from the Colorado Division of Water Resource's Decision Support Systems website: http://cdss.state.co.us/

Scaling Rationale: The scaling is based on best scientific judgment. Additional research is needed and may suggest changes to the scaling criteria.

Confidence that reasonable logic and/or data support the index: Low/Medium.

▪ B.3.5. Surface Water Runoff Index

Definition: The surface water runoff index is a measure of the varying degrees to which different land uses alters surface water runoff and overland flow into a wetland.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: The type and amount of each land use in the wetland and contributing watershed affects the timing, duration, and frequency of surface water runoff and overland flow into a wetland. These flows alter the hydrological regime of the wetland and can result in degradation of biotic integrity, change nutrient cycling, and potentially affect physical integrity.

In a functional assessment of slope and depressional wetlands associated with the Great Salt Lake, Keate (2005) developed a HGM assessment model primarily based on land use as a surrogate for human impacts on wetland functions. Coefficients from Nnadi (1997) were used to represent the sediment, nutrient loading, runoff, and wildlife impacts associated with various land uses. The functions considered included hydrologic, geochemical and habitat characteristics. The same coefficients used in the Keate (2005) method are used for this metric.

Measurement Protocol: Identify and estimate the percentage of each land use within the wetland and the contributing watershed (within 100 m of the wetland). This is best completed in the field, however with access to current aerial photography a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use. Once the percentage of each land use is identified, multiply it by the corresponding Surface Water Runoff coefficient found for each land use in Appendix B, then sum for the Surface Water Index Score.

For example, if 50% of the wetland and contributing watershed (within 100 m of the wetland) was under heaving grazing, 10% had a dirt road, and 40% natural vegetation the calculation would be (0.5 * 0.76) + (0.1 * 0.71) + (0.4* 1.0) = 0.85 (Surface Water Index Score). Referring to the scorecard, this would give the metric a “Fair” rating.

The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. Surface water divides are determined using topography and although groundwater divides do not always coincide with these same hydrological divides, groundwater movement is assumed to do so, unless other data for the site is available

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7

Data: Appendix B.

Scaling Rationale: The scaling is based on best scientific judgment. Scores below 0.7 are assumed to have crossed a threshold in which runoff impacts are considered to not be restorable (based on the land uses that have coefficients below 0.7). Additional research may suggest changes to the scaling criteria.

Confidence that reasonable logic and/or data support the index: Medium.

- ### B.3.6. Index of Hydrological Alteration

Definition: This metric uses daily streamflow data to determine trends at one site or determine differences between pre- and post-impacts of sites.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: The Index of Hydrological Alteration (IHA) is an easy to use tool for calculating the characteristics of natural and altered hydrologic regimes using any type of daily hydrologic data, such as streamflows, river stages, ground water levels, etc. Rather that review the entire method here, please refer to http://www.freshwaters.org/tools to download the IHA software as well as supporting documentation, including numerous published papers.

Measurement Protocol: Long-term daily streamflow data are required for this metric. If those are not available daily flow data may be generated using a hydrologic model or other simulation method (see Richter et al. 1997). The IHA statistics will be meaningful only when calculated for a sufficiently long hydrologic record. The length of record necessary to obtain reliable comparisons is currently being researched, however it is recommended that at least twenty years of daily records be used (see Richter et al. 1997).

Some lake level and ground water well data are also available from the USGS, but much of this type of data is collected and managed by other local governmental entities.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
No significant change from Reference Hydrographs	Slight change from Reference Hydrographs	Moderate change from Reference Hydrographs	Large change from Reference Hydrographs

Data:
Index of Hydrologic Alteration Software and Supporting Documentation: http://www.freshwaters.org/tools

U.S. Geological Survey Streamflow Data: http://water.usgs.gov/usa/nwis. (data can be imported directly in the IHA)

The U.S. Forest Service, U.S. Bureau of Land Management, and local government agencies may have streamflow data for some of the streams located on the lands they manage.

Scaling Rationale: The scaling is based on best scientific judgment of deviation from the reference standard. Additional research may suggest changes to the scaling criteria.

Confidence that reasonable logic and/or data support the index: Medium/High.

- ### B.3.7. Bank Stability

Definition: This metric assesses the stability and condition of the streambanks.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Unstable or eroding banks are often the results of local and/or upstream impacts associated with channel incision induced by over grazing and/or upstream alterations in the hydrological and/or sediment regimes. The local impact from eroding or unstable banks is typically a drop in the local water table along with a change in composition of plant species growing along the streambanks.

Measurement Protocol: This metric is measured by walking along the streambanks in the riparian area and observing signs of eroding and unstable banks. These signs include crumbling, unvegetated banks, exposed tree roots, exposed soil, as well as species composition of streamside plants (Barbour et al. 1999; Prichard et al. 1998). Stable streambanks are vegetated by native species that have extensive root masses (*Alnus incana*, *Salix* spp., *Populus* spp., *Betula* spp., *Carex* spp., *Juncus* spp., and some wetland grasses) (Prichard et al. 1998). In general, most plants with a Wetland Indicator Status of

OBL (obligate) and FACW (facultative wetland) have root masses capable of stabilizing streambanks while most plants with FACU (facultative upland) or UPL (upland) do not (Prichard et al. 1998; Reed 1988).

Each bank is evaluated separately then averaged to assign the metric rating.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Banks stable; evidence of erosion or bank failure absent or minimal; < 5% of bank affected. Streambanks dominated (> 90% cover) by Stabilizing Plant Species (OBL & FACW)	Mostly stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion. Streambanks have 75-90% cover of Stabilizing Plant Species (OBL & FACW)	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods. Streambanks have 60-75% cover of Stabilizing Plant Species (OBL & FACW)	Unstable; many eroded areas; "raw". Areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars. Streambanks have < 60% cover of Stabilizing Plant Species (OBL & FACW)

Data:
Wetland Indicator Status: U.S. Fish and Wildlife Service, National Wetlands Inventory website: http://www.nwi.fws.gov/plants.htm or USDA PLANTS Database: http://plants.usda.gov/

The Colorado Floristic Quality Index Database will also have Wetland Indicator Status information.

Scaling Rationale: The scaling is based on Barbour et al. (1999), Prichard et al. (1998), and best scientific judgment of deviation from the reference standard. Additional research may suggest changes to the scaling criteria.

Confidence that reasonable logic and/or data support the index: Medium.

▪ B.3.8. Litter Cover

Definition: The percent cover of plant litter or detritus covering the soil surface.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Litter cover provides an indication of the amount of organic matter produced and recycled in the wetland. Disturbed wetlands and riparian areas often have different amounts of litter cover than reference sites due to a change in species composition, productivity, and decomposition.

Measurement Protocol: Litter cover is measured using the same protocols as vegetation. A qualitative, ocular estimate of litter cover is used to calculate and score the metric. The entire occurrence of the riparian system should be walked and a qualitative ocular estimate of the total cover of litter in the wetland should be made. Alternatively, if time and resources allow a more quantitative determination of species presence and cover such methods (i.e. Peet et al. 1998) are encouraged to be used. The metric is scored by comparing current litter cover values to those of reference or baseline conditions.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
No significant change from Reference Amount	Slight change from Reference Amount	Moderate change from Reference Amount	Large change from Reference Amount

Data: The Colorado Vegetation Index of Biotic Integrity project will likely provide the necessary data to establish the range of litter cover found in undisturbed examples.

Scaling Rationale: The criteria are based on best scientific judgment.

Confidence that reasonable logic and/or data support the index: Low/medium.

B.3.9. Nutrient/Pollutant Loading Index

Definition: The nutrient/pollutant loading index is a measure of the varying degrees to which different land uses contributed excess nutrients and pollutants via surface water runoff and overland flow into a wetland.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: The type and amount of each land use in the wetland and contributing watershed affects the amounts and types of nutrients and pollutants that enter into a wetland. Excess nutrients can result in degradation of biotic integrity, change nutrient cycling, and potentially affect peat integrity.

In a functional assessment of slope and depressional wetlands associated with the Great Salt Lake, Keate (2005) developed a HGM assessment model primarily based on land use as a surrogate for human impacts on wetland functions. Coefficients from Nnadi (1997) were used to represent the sediment, nutrient loading, runoff, and wildlife impacts associated with various land uses. The functions considered included hydrologic, geochemical and habitat characteristics. The same coefficients used in the Keate (2005) method are used for this metric.

Measurement Protocol: Identify and estimate the percentage of each land use within the wetland and the contributing watershed (within 100 m of the wetland). This is best completed in the field, however with access to current aerial photography a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use. Once the percentage of each land use is identified, multiply it by the corresponding Nutrient/Pollutant Loading coefficient found for each land use in Appendix B, then sum for the Nutrient/Pollutant Loading Index Score.

For example, if 50% of the wetland and contributing watershed (within 100 m of the wetland) was under heaving grazing, 10% had a dirt road, and 40% natural vegetation the calculation would be (0.5 * 0.87) + (0.1 * 0.92) + (0.4* 1.0) = 0.93 (Surface Water Index Score). Referring to the scorecard, this would give the metric a "Good" rating.

The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. Surface water divides are determined using topography and although groundwater divides do not always coincide with these same hydrological divides, groundwater movement is assumed to do so, unless other data for the site is available

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7

Data: Appendix B.

Scaling Rationale: The scaling is based on best scientific judgment. Scores below 0.7 are assumed to have crossed a threshold in which loading impacts are considered to not be restoreable (based on the land uses that have coefficients below 0.7). Additional research may suggest changes to the scaling criteria.

Confidence that reasonable logic and/or data support the index: Low/medium.

▪ B.3.10. Nutrient Enrichment (C:N)

Definition: The carbon to nitrogen (C:N) ratio in the aboveground biomass or leaves of plants is used to determine whether there is excess N in the system (compared to reference standard). Increasing leaf N decreases the C:N ratio and indicates nitrogen enrichment.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Nitrogen enrichment causes vegetation to increase uptake and storage of nitrogen in plant tissue and generally results in increased productivity (Craft et al. 1995, Bridgham et al. 1996 *in* U.S. EPA 2002). These changes affect ecosystem processes including decomposition (Valiela et al. 1982, Davis 1991, Rybczyk et al. 1996 *in* U.S. EPA 2002) and accumulation of soil organic matter (Craft and Richardson 1993, 1998, Morris and Bradley 1999 *in* U.S. EPA 2002). Floristic composition may change as aggressive, competitive species take advantage of increased nutrients and displace less competitive species. All of these changes degrade the ecological integrity of the wetland by altering energy flow, nutrient cycling, and potential habitat for fauna assemblages (U.S. EPA 2002).

Measurement Protocol: Herbaceous plants are preferentially sampled because they respond to nutrient enrichment quicker than woody species (U.S. EPA 2002). Two or three dominant species should be selected for sampling. Samples should be collected from plants of a similar age and clipped from nodes a similar distance below the terminal bud (U.S. EPA 2002). The plants should be growing in similar habitats. If habitat is heterogeneous, then it is best to sample from each dominant habitat type. Multiple samples should be collected from several individual plants (5-10) to capture variability within the population. It is important to make collections from the same species at each site so that variation in leaf tissue nutrient concentrations is minimized (U.S. EPA 2002). See U.S. EPA (2002) for additional information.

Nitrogen is typically measured by dry combustion using a CHN analyzer. Each clipped sample should be placed in their own individual paper bag and sent to a laboratory for analysis of soil organic carbon (e.g., CHN Analyzer). Do not put the sample in a plastic bag as this could induce decomposition of the sample.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Leaf tissue C:N is equivalent to natural range of variability	Leaf tissue C:N is slightly less and outside of natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability

Data: N/A

Scaling Rationale: Reference C:N ratios need to be established in undisturbed wetlands and riparian areas. Thereafter, the scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of nutrient enrichment. If data are collected from wetlands and riparian areas across a disturbance gradient, quantitative criteria could be established.

Confidence that reasonable logic and/or data support the index: Medium/High.

- ### B.3.11. Nutrient Enrichment (C:P)

Definition: The carbon to phosphorous (C:P) ratio in the aboveground biomass or leaves of plants is used to determine whether there is excess P in the system (compared to reference standard). Increasing leaf P decreases the C:P ratio and indicates phosphorous enrichment.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Phosphorous enrichment causes vegetation to increase uptake and storage of phosphorous in plant tissue and generally results in increased productivity (Craft et al. 1995, Bridgham et al. 1996 *in* U.S. EPA 2002). These changes affect ecosystem processes including decomposition (Valiela et al. 1982, Davis 1991, Rybczyk et al. 1996 *in* U.S. EPA 2002) and accumulation of soil organic matter (Craft and Richardson 1993, 1998, Morris and Bradley 1999 *in* U.S. EPA 2002). Floristic composition may change as aggressive, competitive species take advantage of increased nutrients and displace less competitive species. All of these changes degrade the ecological integrity of the wetland by altering energy flow, nutrient cycling, and potential habitat for fauna assemblages (U.S. EPA 2002).

Measurement Protocol: Herbaceous plants are preferentially sampled because they respond to nutrient enrichment quicker than woody species (U.S. EPA 2002). Two or three dominant species should be selected for sampling. Samples should be collected from plants of a similar age and clipped from nodes a similar distance below the terminal bud (U.S. EPA 2002). The plants should be growing in similar habitats. If habitat is heterogeneous, then it is best to sample from each dominant habitat type. Multiple samples should be collected from several individual plants (5-10) to capture variability within the population. It is important to make collections from the same species at each site so that variation in leaf tissue nutrient concentrations is minimized (U.S. EPA 2002). See U.S. EPA (2002) for additional information.

Phosphorous is typically measured by spectrophotometry in acid (H_2SO_4-H_2O_2) digests. Each clipped sample should be placed in their own individual paper bag and sent to a laboratory for analysis of soil organic carbon (e.g., CHN Analyzer). Do not put the sample in a plastic bag as this could induce decomposition of the sample.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Leaf tissue C:P is equivalent to natural range of variability	Leaf tissue C:P is slightly less and outside of natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability

Data: N/A

Scaling Rationale: Reference C:P ratios need to be established in undisturbed wetlands and riparian areas. Thereafter, the scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of nutrient enrichment. If data are collected from wetlands and riparian areas across a disturbance gradient, quantitative criteria could be established.

Confidence that reasonable logic and/or data support the index: Medium/High.

- ### B.3.12. Soil Organic Matter Decomposition

Definition: This metric indicates the amount of decomposition of soil organic matter present in the soil and thus is an indicator measure of nutrient cycling.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Soil organic matter generally refers to the organic fraction of the soil, including plant and animal residues at various stages of decomposition, as well as substances synthesized by the soil organisms (Neue 1984). Organic matter plays an extremely important role in the soil environment, including increasing water holding capacity, encouraging soil structure, has a high cation exchange capacity, and supplies essential nutrients (Brady 1990).

Soil organic matter is accumulated in both the O and surface soil (either A or E) horizons in the soil profile. In some riparian areas, soils can be poorly developed, thus the A and E horizons are lumped into a "surface mineral soil horizon" (SMS-horizons) category for this metric (Hauer et al. 2002). The O horizon is found on the soil surface and is composed of various stages of decomposition. The SMS-horizons accumulate highly decomposed organic matter (e.g., humus), which often gives the horizon a dark, black color and high amount of colloids (Brady 1990).

Deviation of the depth of the O horizon from reference conditions indicate under- or over-abundance or too fast or slow of a decomposition rate (Hauer et al. 2002). The depth and color of the SMS-horizons is used in this metric as an index of the ability of the soil to store nutrients and thus changes from reference conditions are assumed to be indicators of changes in the input of organic matter as well in nutrient cycling (Hauer et al. 2002). For example, human disturbance may cause lower productivity resulting in thinner and lighter colored SMS-horizons (Hauer et al. 2002). Alternatively, thicker SMS-horizons than the reference standard may result from increased sedimentation (Hauer et al. 2002).

Measurement Protocol: The metric is calculated as an Organic Matter Decomposition Factor (OMDF) based on the depth of the O-horizon, the depth of the SMS-horizon, and the soil color value (from Munsell Soil Chart) of the SMS-horizon (Hauer et al. 2002).

Multiple soil pits should be dug in the wetland to a depth where the lower boundary of the SMS-horizon is detected. If quantitative vegetation data are being collected, soil pits should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil pits would be located within each of the intensive modules. The thickness of the O and SMS-horizons should be measured and the soil color estimated using a Munsell Soil Color Chart.

The OMDF is calculated as: $\text{OMDF} = \left[\left(DepthOhorizon \right) + \left(\frac{DepthSMShorizon}{SoilColorValue} \right) \right]$

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
OMDF > 4.75	OMDF 3.0 - 4.75	OMDF 1.25 - 3.0	OMDF < 1.25

Data: N/A

Scaling Rationale: The reference OMDF values are based on the work of Hauer et al. (2002) who found that riparian shrublands (e.g., willows and alders) and wet meadows in riverine floodplains in the Northern Rockies had OMDF values > 1.8. This reference value is tentatively used for Southern Rocky Mountain riparian shrublands, but additional data collection may suggest alternative values.

The scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of disturbance. If data are collected from wetlands and riparian areas across a disturbance gradient, quantitative criteria could be established. Alternatively if “baseline” OMDF levels are known (from “pre-impact” conditions or from adjacent unaltered sites) then this metric can be used to determine change of OMDF with time.

Confidence that reasonable logic and/or data support the index: Medium.

- **B.3.13. Soil Organic Carbon**

Definition: This metric measures the amount of soil organic carbon present in the soil.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Soil organic matter or carbon generally refers to the organic fraction of the soil, including plant and animal residues at various stages of decomposition, as well as substances synthesized by the soil organisms (Neue 1984). Organic matter plays an extremely important role in the soil environment, including increases water holding capacity, encouraging soil structure, has a high cation exchange capacity, and supplies essential nutrients (Brady 1990).

Soil organic carbon is strong metric of soil quality due to its sensitivity to environmental disturbance (NRC 2000 *in* Fennessy et al. 2004). Given that soil organic carbon contributes to critical hydrologic, biogeochemical, and physical processes, a reduction in soil organic carbon from reference conditions serves as a strong indicator of loss of soil quality.

Measurement Protocol: Multiple soil pits should be dug in the wetland to a depth of at least 40 cm. If quantitative vegetation data are being collected, soil pits should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil pits would be located within each of the intensive modules. At least five replicate soil samples should be taken within the top 10 cm of the soil surface in each pit. The replicates are mixed together as “one” sample from the site. Each soil sample should be placed in their own individual plastic bag, packed on ice, and sent to a laboratory for analysis of soil organic carbon (e.g., CHN Analyzer).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Soil C is equivalent to natural range of variability	Soil C is nearly equivalent to natural range of variability	Soil C is significantly lower than natural range of variability	Soil C is significantly lower than natural range of variability

Data: N/A

Scaling Rationale: Reference soil organic carbon levels need to be established in undisturbed wetlands and riparian areas. Thereafter, the scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of disturbance. If data are collected from wetlands and riparian areas across a disturbance gradient, quantitative criteria could be established. Alternatively, if "baseline" soil organic carbon levels are known (from "pre-impact" conditions or from adjacent unaltered sites) then this metric can be used to determine change of soil organic carbon with time.

Confidence that reasonable logic and/or data support the index: Medium/High.

- ### B.3.14. Soil Bulk Density

Definition: Soil bulk density is a ratio of the mass/volume of the soil. This metric is a measure of the compaction of the soil horizons.

Background: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Bulk density is a measure of the weight of the soil divided by its volume and provides an indication of the level of compaction. Compaction can result from any activity which compresses soil particles thereby increasing the weight to volume ratio. This can reduce the soil's water holding capacity, infiltration rate, water movement through the soil, and limit plant growth by physically restricting root growth (NRCS 2001). Bulk density of organic soils are typically much less than those of mineral soils, however as decomposition increases and/or organic soils are compacted from human activity, bulk density of organic soils will increase. This has corresponding negative impacts on ecological processes such as water movement through the peat body, decomposition, and nutrient cycling.

Measurement Protocol: Multiple soil pits should be dug in the wetland to a depth of at least 40 cm. If quantitative vegetation data are being collected, soil pits should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil pits would be located and samples collected within each of the intensive modules.

The samples are collected by taking a core sample within the top 15 cm of the soil. A cylinder of known volume should be used to collect samples. A PVC pipe of known dimensions will suffice. The cylinder is simply inserted into the soil profile, extracted, then shaved to eliminate any soil which is not contained within the cylinder. The soil remaining in the cylinder can then be placed into a plastic bag and then sent to a laboratory for analysis. Bulk density and soil texture (e.g., particle distribution) should be analyzed. Alternatively, texture can be determined in the field using the "field hand method", however lab analysis is preferable.

Once texture and bulk density are determined, use the information below to determine whether the soil's bulk density is less than, equal to, or greater then the minimum root-restricting bulk density values listed for the corresponding texture of the soil and assign the metric rating accordingly in the scorecard.

There are no root restricting values given for organic soils, thus if the wetland is dominated by organic soil, reference bulk density measurements need to be established in undisturbed areas.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland.	Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland. (same as Very Good)	Bulk density for wetland is between 0.2 to 0.1 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland.	Bulk density for wetland is = or > than Root Restricting Bulk Density value for the soil texture found in the wetland.

Data: The data below are derived from a Natural Resource Conservation Service, Soil Quality Information Sheet — Compaction which can be found online at: http://soils.usda.gov/sqi/publications/sqis.html

Theses texture classes have the following Root Restricting Bulk Density values (g/cm3):

1. Coarse, medium, and fine sand AND loamy sand other than loamy very fine sand = 1.8 g/cm3
2. Very fine sand, loamy very find sand = 1.77 g/cm3
3. Sandy loam = 1.75 g/cm3
4. Loam, sandy clay loam = 1.7 g/cm3
5. Clay loam = 1.65 g/cm3
6. Sandy clay = 1.6 g/cm3
7. Silt, silt loam = 1.55 g/cm3
8. Silty clay loam = 1.5 g/cm3
9. Silty clay = 1.45 g/cm3
10. Clay = 1.4 g/cm3

Scaling Rationale: The scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of disturbance. However, no distinction was made between Excellent and Good as there is no information to suggest that threshold. Alternatively if "baseline" bulk density levels are known (from "pre-impact" conditions or from adjacent unaltered areas) then this metric can be used to determine change of bulk density with time.

Confidence that reasonable logic and/or data support the index: Medium/High.

B.4 Size Metrics

- **B.4.1. Absolute Size**

Definition: Absolute size is the current size of the wetland.

Background: This metric is one aspect of the size of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Absolute size is pertinent to ecological integrity if the surrounding landscape is impacted by human-induced disturbances. When the surrounding landscape is impacted and has the potential to affect the wetland, larger sized wetlands and riparian areas are able to buffer against these impacts better than smaller sized wetlands and riparian areas due to the fact they generally possess a higher diversity of abiotic and biotic processes allowing them to recover and remain more resilient. However, when the landscape is unimpacted (i.e. has an "Excellent" rating), then absolute size has little impact on ecological integrity since there are no adjacent impacts to buffer. Of course, larger wetlands and riparian areas tend to have more diversity (MacArthur and Wilson 1967); however, this is a metric more pertinent to functional or conservation value than ecological integrity. Thus, absolute size is included as a metric but is only considered in the overall ecological integrity rank if the landscape is impacted. Regardless, absolute size provides important information to conservation planners and land managers.

Measurement Protocol: Absolute size can be measured easily in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, etc. Absolute size can also be estimated in the field using 7.5 minute topographic quads, National Wetland Inventory maps, or a global positioning system. Wetland boundaries aren't delineated using jurisdictional methods (U.S. Army Corps of Engineers 1987) rather by the guidelines identified for delineating the boundaries of the wetland ecological system type.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
> 8.0 linear km (minimum of 10 m wide)	5.0 to 8.0 linear km (minimum of 10 m wide)	1.5 to 5.0 linear km (minimum of 10 m wide)	< 1.5 linear km (minimum of 10 m wide)

Data: N/A

Scaling Rationale: Scaling criteria are based on Rondeau (2001) and best scientific judgment.

Confidence that reasonable logic and/or data support the index: Medium/High.

- ### B.4.2. Relative Size

Definition: Relative size is the current size of the wetland divided by the total potential size of the wetland multiplied by 100.

Background: This metric is one aspect of the size of specific occurrences of wetland and riparian ecological systems.

Rationale for Selection of the Variable: Relative size is an indication of the amount of the wetland lost due to human-induced disturbances. It provides information allowing the user to calibrate the Absolute Size metric to the abiotic potential of the wetland onsite. For example, if a wetland has an Absolute Size of 2 hectares but the Relative Size is 50% (1 hectare), this indicates that half of the original wetland has been lost or severely degraded. Unlike Absolute Size, the Relative Size metric is always considered in the ecological integrity rank.

Measurement Protocol: Relative size can be measured in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, etc. However, field calibration of size is required since it can be difficult to discern the abiotic potential of the wetland from remote sensing data. However, the reverse may also be true since old or historic aerial photographs may indicate a larger wetland than observed in the field. Relative size can also be estimated in the field using 7.5 minute topographic quads, National Wetland Inventory maps, or a global positioning system. Wetland boundaries aren't delineated using jurisdictional methods (U.S. Army Corps of Engineers 1987) rather by the guidelines identified for delineating the boundaries of the wetland ecological system type.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Wetland area = onsite Abiotic Potential	Wetland area < Abiotic Potential; < 10% of wetland has been reduced (destroyed or severely disturbed e.g change in hydrology) due to roads, impoundments, development, human-induced drainage, etc.	Wetland area < Abiotic Potential; 10-25% of wetland has been reduced (destroyed or severely disturbed e.g change in hydrology) due to roads, impoundments, development, human-induced drainage, etc.	Wetland area < Abiotic Potential; > 25% of wetland has been reduced (destroyed or severely disturbed e.g change in hydrology) due to roads, impoundments, development, human-induced drainage, etc.

Data: N/A

Scaling Rationale: Scaling criteria are based on Rondeau (2001) and best scientific judgment.

Confidence that reasonable logic and/or data support the index: Medium/High.

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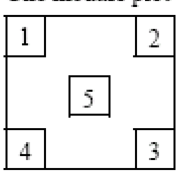
APPENIDX A: FIELD FORMS

Scorecard Field Form, pg 1 of 5

General Information	Location	Site Characteristics
Project	General:	Elevation (m/ft):
Team:	County:	Slope (deg):
Plot:	USGS quad:	Aspect (deg):
Date (Start): / /	Ownership:	Compass: magnetic /corrected
Date (End): / /	GPS location in plot: x= y=	Buffer width:
	UTM Zone: 13	% unfragmented area of wetland:
Plot Documentation	Uncorrected — UTM-E:	
Cover method:	Uncorrected — UTM-N:	**Land use w/in 100m of wetland**
	Uncorrected — Coord. Accuracy (m radius):	Types: / Relative %:
Photos		
Film roll: /Frame(s)	GPS File Name:	
Focal length:	T: R: S:	

Map: Fill in the template below (2 modules or more) or right (1 module plot), using the guide at far right. Also note actual arrangement of modules, which corners were sampled, and location of any witness trees.

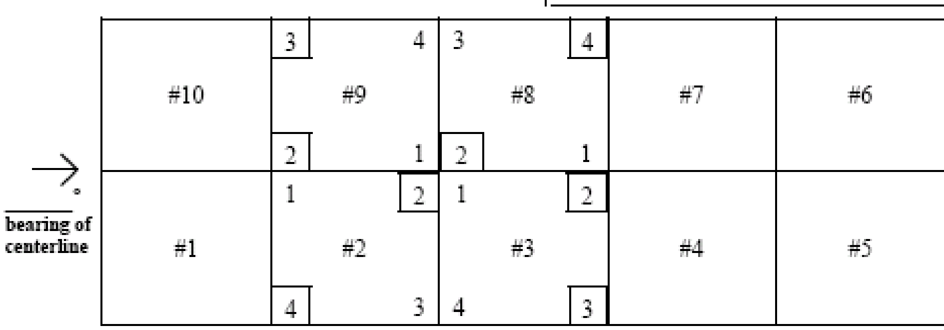
One module plot



⊗ GPS location point

○→ photo taken, with direction

● location of permanent posts



Land use in contributing watershed

Ground watershed	
Surface watershed	

Physiognomic Class*

__ I Forest
__ II Woodland
__ III Shrubland
__ IV Dwarf Shrubland
__ V Herbaceous
__ VI Nonvascular
__ VII Sparsely vegetated

Leaf Type*

__ B Broad-leaved
__ N Needle-leaved
__ M Microphyllous
__ G Graminoid
__ F Forb
__ P Pteridophyte

Leaf Phenology*

__ EG Evergreen
__ CD Cold-deciduous
__ DD Drought- deciduous
__ MC Mixed evergreen- cold deciduous
__ MD Mixed evergreen- drought deciduous

Soil Chemistry*

____ pH

____ Conductivity

____ Temperature

Cowardin System*

__ UPL Upland
__ EST Estuarine
__ RIP Riparian
__ PAL Palustrine
__ LAC Lacustrine

Community Classification*

CNHP Type ____________________
Cowardin ____________________
HGM____________________
Classifier ____________________
Date ____________________

** Definitions and/or values are in the Reference section of the Pulse Field Guide

Scorecard Field Form, pg 2 of 5

Present?	Biotic/abiotic patch type
	Open water –stream
	Open Water - Pools
	Open Water – Rivulets/Streams –fen
	Open water – beaver pond
	Oxbow/backwater channels
	Tributary or secondary channels
	Streams – pool/riffle complex
	Active beaver dams
	Wet meadows
	Occasional trees
	Point bars
	Adjacent hillside seeps/springs
	Beaver canals
	Interfluves on floodplain
	Debris jams (woody debris) in stream
	Mudflats
	Saltflats
	Submerged/floating vegetation
	Emergent vegetation
	Moss bed
	Occasional shrubs
	Emergent vegetation
	Hummock/tussock - fen
	Water Tracks/Hollows - fen
	Lawns - fen
	Floating Mat - fen
	Spring fen
	Shrubs - fen
	Marl/Limonite beds - fen

Ground Cover (%)

Bryo/lichen:	Sand/soil:
Decaying wood:	Water:
Bedrock/boulder:	Litter/OM:
Gravel/cobble:	Other

Cover by Strata

Canopy height (m):

Abr.	Stratum	Height range (m)	Total Cover (%)
S	Shrub		
F	Forb		
G	Graminoid		
T	Tree		
FL	Floating		
A	Aquatic submerged		

Landform type*: ______________________________

√ one	Interspersion of patches
	Excellent: Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type.
	Good: Horizontal structure consists of a moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type.
	Fair: Horizontal structure consists of a simple array of nested or interspersed biotic/abiotic patches.
	Poor: Horizontal structure consists of one dominant patch type and thus has relatively no interspersion.
	Abundance of willows/cottonwoods
	Excellent: Saplings/seedlings present in expected amount; obvious regeneration
	Good: Saplings/seedlings present but less than expected; some seedling/saplings present
	Fair: Saplings/seedlings present but in low abundance; Little regeneration by native species
	Poor: No reproduction of native woody species
	Beaver Activity
	Excellent: New, recent, and/or old beaver dams present. Beaver currently active in the area.
	Good: Recent and old beaver dams present. Beaver may not be currently active but evidence suggests that have been with past 10 years.
	Fair: Only old beaver dams present. No evidence of recent or new beaver activity despite available food resources and habitat.
	Poor: No beaver dams present when expected (in unconfined valleys).
	Relative Size
	Excellent: Wetland area = outside abiotic potential
	Good: Wetland area < abiotic potential; Relative size = 90 – 100%; (<10% of wetland has been reduced, destroyed or severly disturbed due to roads, impoundments, development, human-induced drainage, etc.
	Fair: Wetland area < abiotic potential; Relative size = 75 – 90%; (10-25% of wetland has been reduced, destroyed or severly disturbed due to roads, impoundments, development, human-induced drainage, etc.
	Poor: Wetland area < abiotic potential; Relative size = <75 – > 25 %; of wetland has been reduced, destroyed or severly disturbed due to roads, impoundments, development, human-induced drainage, etc.

** Definitions and/or values are in the Reference section of the Pulse Field Guide

Scorecard Field Form, pg 3 of 5

Diversions in/near wetland?	**Water Source (√ one)**	
	Ground water	
	Seasonal surface water	
	Permanent surface	
	Precipitation	

Layout Notes: (anything unusual about plot layout and shape)

Location Notes: (include why location was chosen and a small map, more space on reverse)

Hydro Regime*

__ SP Semipermanently flooded
__ SE Seasonally flooded
__ ST Saturated
__ TM Temporarily flooded
__ IN Intermittently flooded
__ PR Permanently flooded
__ TD Tidally flooded
__ IR Irregularly flooded
__ IE Irregularly exposed
__ UN Unknown
__ RD Rapidly drained
__ WD Well drained
__ MW Moderately well drained
__ SP somewhat poorly drained
__ PD Poorly drained
__ VP Very poorly drained

Vegetation Notes: (characterization of community, dominants, and principle strata)

Additional Notes:

Topographic Position *

__ H interfluve (crest,summit,ridge)
__ E High slope (shoulder, upper, convex)
__ M High level
__ D Mid slope
__ F Back slope (cliff)
__ C Low slope (lower, foot, colluvial)
__ B Toeslope
__ G Low level (terrace)
__ J Channel wall (bank)
__ K Channel bed (valley bottom)
__ I Basin floor (depression)

** Definitions and/or values are in the Reference section of the Pulse Field Guide

Scorecard Field Form, pg 4 of 5

Soils Data

Horizon	Range (depth cm)	Texture	Soil & Mottle Color	Depth to water table (cm)	Depth to Saturated Soils (cm)	Depth of Peat (cm)	Structure	% Coarse (Est.% per horizon by type- gravel, cobble, boulder)	Comments (90% root depth, charcoal, etc.) Mottle Abundance(few <2%, common 2-20%, many >20%), Size (fine <5 mm dia., medium 5-15 mm, large >15 mm) and Contrast (faint-similar to matrix, distinct-contrast slightly, prominent-mottles vary by several units of hue, value or chroma)

Scorecard Field Form, pg 5 of 5

Vegetation Plot data (see Carolina Vegetation Survey for digital versions of their data forms: http://www.bio.unc.edu/faculty/peet/lab/CVS/)

Species Code	2	2	2	4	3	2	3	3	8	2	8	4	9	2	9	3	R	R

APPENDIX B: SUPPLEMENTARY DATA

Coefficient Table (coefficients were calculated from numerous studies throughout the U.S. (Keate (2005)

Land Use	Surface Water Runoff	Nutrient/ Pollutant Loading	Suspended Solids
Natural area	1.00	1.00	1.00
Dirt Road (dirt or crushed or loose gravel, unpaved roads, local traffic)	0.71	0.92	0.90*
Field Crop (actively plowed field)	0.95	0.94	0.85**
Clearcut forest	0.83	0.93	0.98
Golf Course (area manipulated for golf, manicured grass)	0.75	0.86	0.94
High Intensity Commercial (area is entirely of commercial use and paved - shopping malls, construction yards)	0.13	0	0
High Traffic Highway (4 lanes or larger, railroads)	0.26	0.43	0.48
Industrial (intense production activity occurs on a daily basis - oil refineries, auto body and mechanic shops, welding yards, airports)	0.25	0.54	0
Feedlot, Dairy	0.62	0	0.81
Heavy grazing - Non-rotational grazing (year-round or mostly year-round grazing, vegetation is sparse and area trampled)	0.76	0.87	0.85***
Rotational Grazing (grazing is for short periods during the year, vegetation is allowed to recover)	0.96	0.95	0.98
Light Intensity Commercial (businesses have large warehouses and showrooms - large patches of vegetation occur between buildings)	0.19	0.64	0.02
Low Density Rural Development (areas of small structures in a farm or ranch setting - silos, barns)	0.87	0.92	0.98
Low Traffic Highway (2-3 lane paved highways)	0.26	0.69	0.16
Multi-family Residential (subdivisions with lots ½ acre or less)	0.38	0.55	0.61
Nursery (business where the production of nursery grade vegetation occurs including greenhouses, outbuildings and sales lots)	0.86	0.94	1.00
Orchards	0.86	0.93	0.99
Waterfowl Management Areas	0.86	0.91	0.98
Single Family Residential (residential lots are greater than ½ acre with vegetation between houses)	0.75	0.86	0.94
Surface Solid Waste (landfills and waste collection facilities)	0.71	0.87	0.61
Sewage Treatment Plants and Lagoons	0.60	0.61	0.71
Mining	0.76	0.94	0.80

* changed value from 0.97; ** changed value from 1.00; *** changed value from 0.98